ROBOTICS MICROCONTROLLERS COMPUTER CONTROL SPACE

Everything For Electronics

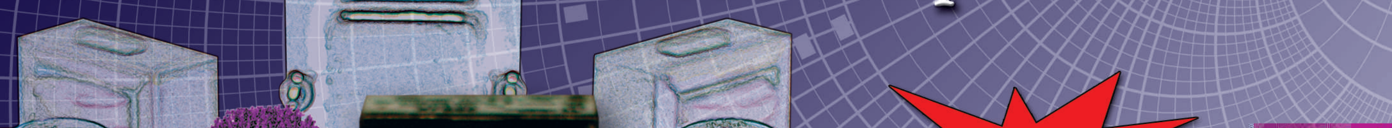
Nuts & Volts

August 2004

www.nutsvolts.com

A BLAST FROM THE PAST

Build a Stereo Tube Amp



contents

August 2004
Vol. 25 No. 8

PROJECTS

FEATURES

THE NEXT GENERATION IN COMPETITION:

COLUMNS

NEW Column!

DEPARTMENTS

Nuts & Volts (ISSN 1528-9885/CDN Pub Agree#40702530) is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, 430 Princeland Court, Corona, CA 92879-1300** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com

Answer the challenge of Tetsujin 2004 today!

Every so often, a challenge comes along that is just too good to pass up. If matching your skills and ideas against those of the brightest minds in a competition that is sure to test the limits of technology and imagination gets your hydraulic fluid pumping, then you'll want to be involved. TETSUJIN 2004 is just such an event. A cross between Robot Wars, Monster Garage, and the DARPA Grand Challenge, TETSUJIN 2004 requires competitors who know how to think outside the box.

Held in conjunction with RoboNexus, Tetsujin is already attracting the attention of industry and media.

If you are even considering competing, send an Email to **tetsujin@servomagazine.com** declaring your intent to participate and a short description of your abilities, including your business or academic affiliation (if any), location (city and state), and means of contact (Email or phone).

If we can't pair you up with an existing team, we'll at least add you to our Email list to keep you informed of event info, updates, and deadlines.

RoboNexus

The International Business Development, Educational and Consumer Event For Personal, Service and Mobile Robotics

Santa Clara Convention Center, October 21-23, 2004

www.robonexus.com

Dear Nuts & Volts:

I just read an excellent article by Gerard Fonte on Printed Circuit Board Layout. To many hobbyists, the subject of PC board layout seems mysterious and complicated. It certainly was to me before I became involved in breadboarding circuits in the R & D lab of a semiconductor company. Since most modern circuits make use of surface mount components, PC boards have to be designed in order to test and evaluate new IC designs. We occasionally use small perf boards for the odd add-on circuit to test an idea. I haven't seen wire wrap in more than 10 years.

In other words, PC board layout skills have become an essential part of the lab skills required from engineering personnel. Gerard Fonte's article is a basic — yet very informative — overview on the subject, but I think it needs to be pursued further. An in-depth review of the PC board layout software generally available to hobbyists would be a logical continuation. I know this subject has been covered before, but I don't think it has been covered in enough detail.

A hands-on review would be interesting, as there are several packages out there that claim to do it all. If experience serves me right, that is not the case. Many promise, but few deliver.

Gerald C. Lemay
via Internet

Dear Nuts & Volts:

The vibration effect noticed by Gerard Fonte (June 2004 issue) may not be well documented, but it was a standard part of the engineer's repertoire in Britain in the late 1950s. In those days, radio and TV sets had a "hot" chassis and an unpolarized two-pin AC plug.

Before working on an instrument, you needed to know whether the chassis was connected to the 240 VAC supply or to the neutral wire.

If you didn't have an electrician's neon screwdriver handy, you first checked to be sure you weren't touching a grounded object and then you ran the backs of your fingers along the chassis. The difference between a live and neutral chassis was easy to feel. If the chassis was live, you reversed the power plug before connecting any test instruments.

Tom Napier
North Wales, PA

Dear Nuts & Volts:

I have never put down a copy of *N & V* without clipping something, but — last month — I learned what a stabistor is, what kinds of batteries I can get for my Makita 9.6 V tools, and a way to figure current limits in circuit board traces. I have my Fluke 27 ($300.00) in the refrigerator, recuperating from a slight darkening of the display, a pinout page for three terminal regulators, a check for $25.00 — and those are just the things I can use immediately. You are doing a lot of relevant things for me.

C. L. Larson
Largo, FL

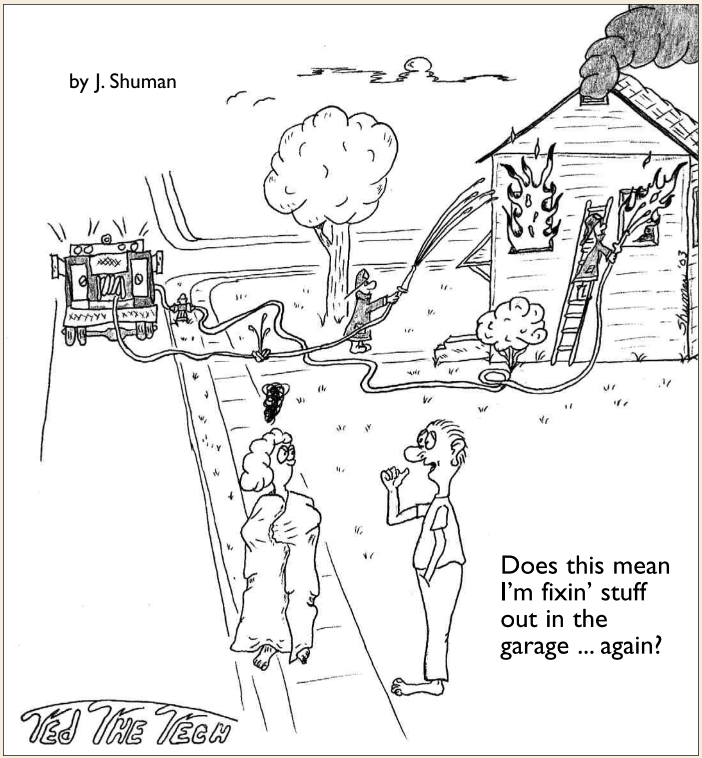
If I correctly pierce your sarcasm, it appears you're in the upper end of the Gaussian curve of experience among N & V readers. That's why we're adding columns, like Peter Best's "Design Cycle," and covering more complex topics, like the Smith Chart. In that article, Christopher Horne addresses real and imaginary components of impedance. Our goal is to continue doing "relevant things" for as many of our readers as possible.

— Editor Dan

Dear Nuts & Volts:

We received the July magazine and found that there is an error with our ad design. The price for the Pocket Digital Video Recorder in the Classifieds should be "$660/kit" instead of "$660/set."

Joseph Qian
Matco



ERRATA ... ERRATA ... ERRATA

The part number of the microcontroller for Michael Chan's "Hand Held Messenger" project in the April 2004 issue was omitted by accident. Listed as a "KK204-04" on page 46, it is a Microchip PIC16C84.

Gerard Fonte's June 2004 "In The Trenches" column was unexpectedly mangled between pages 89 and 90. The text should have read, "Everyone knows that you could roll 100 dice and not get a single '6.' Admittedly, it's a small chance, but it is still clearly possible."

The caption for Figure 4 in Peter Best's article, "Working With Digital Filters," was inadvertently mixed up with the caption for Photo 4 from the author. The correct caption is, "Understanding the math is a good thing, but doing these types of filter kernel inversions by hand would be prohibitive."

Editor Dan

Published Monthly By
T & L Publications, Inc.
430 Princeland Ct., Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
www.nutsvolts.com
Subscription Order ONLY Line
1-800-783-4624

FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING
Robin Lemieux
robin@nutsvolts.com

ADVERTISING SALES DIRECTOR
Rich Collins
rich@nutsvolts.com

MANAGING/TECHNICAL EDITOR
Dan Danknick
dan@nutsvolts.com

ASSOCIATE EDITOR
Alexandra Lindstrom
alexa@nutsvolts.com

CONTRIBUTING EDITORS
Louis Frenzel
Gerard Fonte
Mark Balch
TJ Byers
Jeff Eckert
Paul Verhage
Jon Williams
Mike Keesling
Peter Best
Michael Banks
Christopher Horne
Bob Armstrong
Clifford Appel
Steve Lawson

CIRCULATION DIRECTOR
Mary Descaro
subscribe@nutsvolts.com

SHOW COORDINATOR
Audrey Lemieux

WEB CONTENT/NV STORE
Michael Kaudze
michael@nutsvolts.com

PRODUCTION/GRAPHICS
Shannon Lemieux

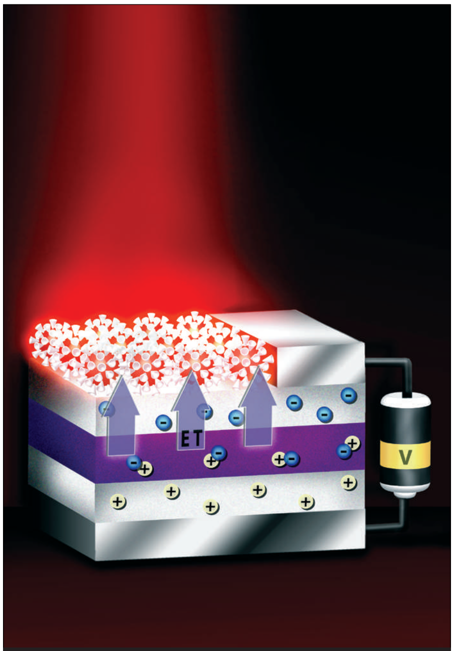
STAFF
Janessa Emond
Kristan Rutz

TechKnowledgey 2004

Events, Advances, and News From the Electronics World

Advanced Technologies

Nanocrystals: Let There Be Light



Voltage applied to a quantum well results in an energy transfer to quantum dots. Photo Courtesy of Los Alamos National Laboratory.

If you have a drawer full of quantum dots and have been wondering if there is some way of getting them to emit light, you're in luck. Scientists working at Los Alamos National Laboratory (**www.lanl.gov**) have discovered a method for doing just that.

According to LANL, "The discovery provides a way to supply energy to quantum dots without wires and paves the way for a potentially wider use of tunable, nanocrystalline materials in a variety of novel, light-emitting technologies ranging from electronic displays to solidstate lighting and electrically pumped nanoscale lasers."

The technique employs non-contact, non-radiative energy transfer from a quantum well (i.e., a semiconductor in which a thin region is surrounded by two energy barriers such that electron motion is confined to two dimensions) to produce light from an adjacent layer of nanocrystals. The key is the use of excitons (bound electron-hole pairs in the semiconductor that recombine to produce photons) for stimulation.

According to Los Alamos Chemistry Division scientist Victor Klimov, "The transfer of energy is fast enough to compete with exciton recombination in the quantum well and that allows us to 'move' more than 50 percent of the excitons to adjacent quantum dots. The recombination of these transferred excitons leads to emission of light with color that can be controlled by quantum dot size.

The high efficiency of energy transfer in combination with the exceptional luminescent properties of nanocrystal quantum dots make hybrid quantum well/nanocrystal devices feasible as efficient sources of any color light — or even white light."

Quantum dot research at Los Alamos has led to several innovations over the past several years, including new ways to observe and manipulate nanodots and methods for making semiconductor nanocrystals respond to photons by producing multiple electrons as a result of impact ionization. That innovation has potential applications in a new generation of solar cells that would produce as much as 35 percent more electrical output than current devices.

Fuel Cell Innovation

Sandia researchers Cy Fujimoto and Chris Cornelius hold a test micro fuel cell with the Sandia membrane. Photo by Randy Montoya.

A new type of polymer electrolyte membrane (PEM) being developed by researchers at the Department of Energy's Sandia National Laboratories (**www.sandia.gov**) is aimed at development of a micro fuel cell that uses diverse fuels such as glucose, methanol, and hydrogen. Known as the Sandia Polymer Electrolyte Alternative (SPEA), it could help fulfill the need for new, uninterrupted autonomous power sources for sensors, communications, microelectronics, healthcare applications, and transportation.

Recently, the membrane research team, headed by researcher Chris Cornelius, demonstrated that the SPEA could operate as high as 140°C and produce a peak power

of 1.1 W/cm^2 at 2 A/cm^2 at 80°C. Under identical operating conditions, the SPEA material can deliver higher power outputs with methanol and hydrogen than Nafion (which is currently the leading PEM material for fuel cells).

Cornelius noted that a higher-temperature PEM material is one of the goals of the Department of Energy's Hydrogen, Fuel Cells, and Infrastructure Technologies Program.

One milestone, set for the year 2005, is to develop polymer electrolyte membranes for automotive applications that operate at 120°C for 2,000 hours with low membrane interfacial resistance.

The next steps, Cornelius says, are to reduce the internal resistance in the fuel cell membrane electrode assembly, optimize catalyst and ionomer composition, improve the properties of the SPEA material, conduct life cycle testing in a fuel cell environment, and assess the potential value for large scale commercialization of the polymer electrolyte.

"We see this SPEA material as having the potential of being integrated into fuel cells, ranging from microwatts to kilowatts," he explained. "Such a broad power range means that this SPEA could be used in a fuel cell to power everything from sensors, cell phones, laptops, to automobiles."

Computers and Networking

The Next World's Most Powerful Supercomputer

The latest player in the never-ending competition to produce the world's most powerful computer is the Oak Ridge National Laboratory (**www.ornl.gov**). It was recently announced that the lab has been chosen to lead a partnership that, within five years and at a cost of $25 million, will create computational resources for a sustained capacity of 50 trillion calculations (teraflops) per second and a peak capacity of more than 250 trillion teraflops per second. This will considerably surpass the power of the current leader, Japan's 40 teraflop Earth Simulator.

The partnership's timetable calls for increasing the capacity of the existing ORNL Cray X1 computer to 20 teraflops this year and adding a 20 teraflop Cray Red Storm-based machine in 2005.

A key member of the partnership — Argonne National Laboratory — will install a five teraflop IBM Blue Gene computer. A 100 teraflop Cray system at Oak Ridge is planned to be added in 2006, which will be increased to a total of 250 teraflops in 2007.

The supercomputer at ORNL will be housed in a new 170,000 sq ft facility that encompasses a staff of 400 and 40,000 sq ft of space for computer systems and data storage. The machines will draw 12 megawatts of power (... and you think your electric bills are bad).

Audio Blogging Introduced

For the uninitiated, it should be explained that "blog" is short for "web log," which — in its simplest form — refers to a web-based journal that provides a way for others to read and respond to your rambling witticisms. The term "blogger" is variously used to describe a web service that provides this ability and people who post blogs.

You can create your own blogs using any of several available applications (e.g., Userland's Manila and Radio [visit **www.userland.com** for details]), or you can just logonto one of the blogging sites (e.g., **www.blogger.com** or **www.blogit.com**), pick a blog template, and start publishing. It's a dream come true for aspiring writers with time on their hands and no printed outlet for their work. It costs nothing and some bloggers have even reported making money at it.

Although blogging isn't a new concept, an interesting twist is that **blogger.com** now offers a feature called AudioBlogger that lets you call from any telephone and leave an audio message that is immediately posted on your blog as an MP3 audio file.

You can also post links to photos — apparently with no restriction on their content. So, if you fancy yourself a writer

and have any level of exhibitionist tendencies, give it a try. Just try not to break any indecency laws.

Intrusion Protection System Introduced

Determina, Inc. (**www.determina.com**) — a startup enterprise security software company — recently introduced its SecureCore product, designed to eliminate the threats of unknown malicious and destructive worms and computer attacks. Based on the Memory Firewall developed at the Massachusetts Institute of Technology, Determina claims that the product, "eliminates the need for signatures, policies, training, or human intervention and works quietly in the background without generating false positives."

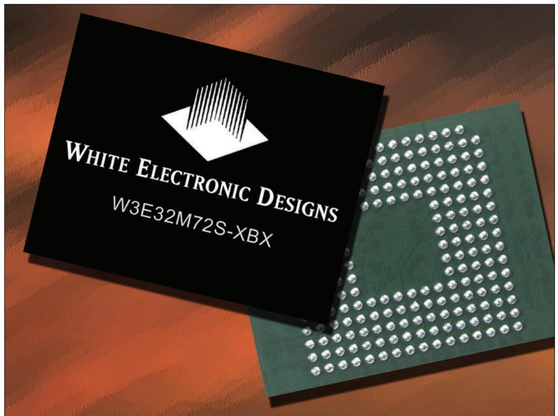
The system consists of two elements: SecureCore Agents and the SecureCore Management Console. The former are deployed on servers, where they protect the operating system, web server, database(s), messaging server, and other system software.

Each agent is said to be foolproof against the most critical class of attacks and capable of running indefinitely without any overhead.

Agents are available for all Windows Services, Internet Information Servers, SQL Servers, and Microsoft Exchange Servers. The management console enables thousands of agents to be deployed and managed across the enterprise and provides a web-based, thin client interface for changing configuration, centralized logging, and event management.

Circuits and Devices

Memory Module for High-Performance Applications



2 Gb DDR SDRAM supports high-performance processor market. Photo Courtesy of White Electronic Designs.

White Electronic Designs Corporation (**www.wedc.com**) recently introduced a 32 M x 72 DDR SDRAM. As the newest member of WEDC's high-density family of double data rate (DDR) SDRAMs, the product is designed to support high-performance processors.

White's 256 MByte (2 Gb) DDR SDRAM features data rates of 200, 250, and 266 Mb/s. The product is organized as a 32 M x 72 package, in a 32 x 25 mm, 219 plastic ball grid array (PBGA).

It is suitable for high reliability applications and is available in commercial, industrial, and military temperature ranges.

Benefits cited by the company include space savings of 40 percent versus a discrete design using a thin small outline package (TSOP), a 34 percent reduction in I/O versus TSOP, and reduced trace lengths for lower parasitic capacitance.

Additionally, the component has a reduced part count versus a discrete design and a reduction in board design complexity. The 32 M x 72 DDR SDRAM, part number W3E32M72S-XBX, is priced at $230.00 (US) each in volumes of 1,000 pieces with a lead time of six weeks.

Temperature Sensor Controls Two Fans

Maxim Integrated Products (**www.maxim-ic.com**) has introduced the MAX6678, a dual

temperature sensor and fan controller that offers remote temperature sensing up to 145°C and automatic adjustment of two cooling fans. Its architecture also has five general purpose I/O (GPIO) pins, which allow a user-programmable startup state without BIOS. These features make the MAX6678 applicable for notebook and desktop computers where VID control, high efficiency, and low noise operation are considerations.

The MAX6678 monitors the temperature of as many as two external diode-connected transistors up to 145°C with ±1°C accuracy. Its SMBus interface makes the data available to the system. The temperature data is also used by the internal PWM fan-speed controller to adjust the speed of two cooling fans, thus minimizing unwanted fan noise and power drain when the system is running cool, but providing maximum cooling when required.

These fans can be programmed to operate with remote channel 1, remote channel 2, or both remote channels.

Additionally, tachometer input of each fan is monitored to ensure correct operation. In the case of failures, fan drive is automatically removed and an ALERT signal can be generated. The GPIO pins can be used for setting POR states, controlling VID, etc. The MAX6678 is targeted at portable applications where acoustic performance, high accuracy, and efficiency are at a premium.

The MAX6678 is offered in the 20-pin QSOP package. It operates from an input voltage range of 3 to 5.5 V and uses 500 µA of supply current. Prices start at $1.75 in quantities of 2,500 or more.

Industry and the Profession

Domain Name Registration Rises

It may be that the world has more than enough websites already, but the world has not yet recognized thatfact. The news from VeriSign, Inc. (**www.verisign.com**), is that more than 4.7 million new domain names were registered during the first three months of 2004, which is the highest quarterly figure in the history of the Internet.

According to Verisign's "VeriSign Domain Report" and "VeriSign Domain Name Registrant Profile," more than 63 million domain names have now been registered — approximately one for every 100 warm bodies on Earth. This number is greater than at any time in the Internet's history, surpassing even the heights that were seen during the Internet "bubble."

Moreover, information reveals that the current base of domain names is being utilized more actively than ever before, as measured by renewal rates, look-up rates, and the percentage of domain names tied to live sites.

A major trend is globalization, with Country Code Top Level Domains (ccTLDs) accounting for 40 percent of all registered domains.

Examples are .de (Germany) and .uk (United Kingdom). Other facts and trends are detailed in the publications, which are available at no cost at **www.verisign.com/domainbrief**

IEEE and SEMI Team Up

Semiconductor Equipment and Materials International (SEMI) — a global industry association serving companies that manufacture semiconductors, flat-panel displays, and micro-electromechanical systems (MEMS) — and the Institute of Electrical and Electronics Engineers (IEEE) have signed a memorandum of understanding to support each other's nanotechnology and MEMS standards. This is the first standards collaboration between the two organizations.

Standards developed by SEMI will address materials, tools, and interfaces, whereas IEEE standards will cover test methods, materials, devices, interoperability, and other topics. IEEE has an active nanotechnology standards effort underway and expects to publish a measurement standard for carbon nanotubes in 2005. For details, visit **http://standards.ieee.org** NV

Basics For Beginners

Just For Starters

Basic Units for DC Circuits

A reader's letter suggested that I explain the basic electrical units used to describe DC circuits. These units are electric potential (expressed in volts, V), current (expressed in amperes, A), resistance (expressed in ohms, Ω), and power (expressed in watts, W). Understanding how these quantities relate to each other allows you to perform basic circuit analysis. Answering questions such as, "How much current does a 100 W load draw on a 12 V battery?" or, "What resistor value is needed to drop 3 V in a 10 mA circuit?" are easy once you learn a few basic principles.

Voltage and Current

Electric potential and current are often the first properties of a circuit that you need to investigate. Electric potential — or voltage — may be considered to be the "pressure" of electricity that is present, while current may be considered as the quantity of electricity actually flowing.

A circuit is a continuous, conductive path that originates at a power source and terminates at that same source. Without continuity, a circuit is broken and current cannot flow.

Consider the circuit in Figure 1, where a circuit is created by placing a resistor across the terminals of a battery.

Current flows from the battery, through the resistor, and back to the battery. Whereas current flows through a circuit, voltage is measured across a circuit. Voltage is measured across the battery's terminals in this example.

While electric potential and current are measured in volts and amps, respectively, these units are often too large for convenient usage. Circuits often deal with thousandths of a volt or amp.

One thousandth is indicated with the prefix "milli," as in 10 milliamps — or 10 mA. You can go lower still and reference millionths and billionths with the prefixes micro and nano.

Ohm's Law

Many people have heard of Ohm's Law. It can be written in many ways, one of which is E = I x R: the electric potential across a resistive load equals the current passing through the load multiplied by the load's resistance. Returning to the circuit in Figure 1, a 10 Ω resistor is placed across the terminals of a 1 V battery.

Ohm's Law tells us that there can be only one current passing through the resistor: 1 V = I x 10 Ω. We can solve for the current, I, by dividing both sides of the equation by 10 Ω, yielding a current of 0.1 A. Ohm's Law indicates that the current through the resistor will decrease as the resistance increases when the voltage is held constant. Similarly, the current increases as the voltage increases when the resistance is held constant.

How you use Ohm's Law often depends on whether you are trying to understand an existing circuit or are designing your own from scratch. An existing circuit is already populated with known resistances, while you must figure out resistances on your own when designing a new circuit. Many projects employ an LED (Light Emitting Diode) to indicate that power is turned on or some other status.

LEDs should not be connected directly to a power source because they can draw too much current and overheat. You can pick a resistor to wire in series between the power source and LED to limit the circuit's current to a safe level. Each LED has a specified operating voltage and current rating. If an LED's voltage is 2 V, with a current of 10 mA, you will want to ensure that connecting the LED to a 5 V source does not cause

Figure 1. A basic circuit.

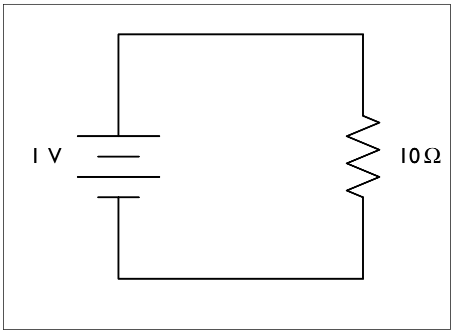
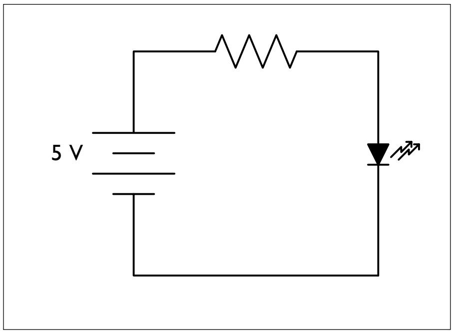


Figure 2. Current limiting an LED.



damage to the device.

The circuit in Figure 2 shows how to protect the LED. Picking a resistor value is made easy by applying Ohm's Law. We know that current is 10 mA, the power source is 5 V, and the LED should operate at 2 V. Therefore, the resistor should drop 3 V. Ohm's Law indicates that 3 V = 10 mA x R and R = 300 Ω. It so happens that 300 Ω is a standard resistor value, but, often, it happens that you calculate a non-standard value. You should select the closest standard value in these situations and err on the side of safety.

For example, if you have a choice in current limiting between a little less current or a little more, err on the side of less to avoid over-stressing the LED.

Power

All circuits consume finite power while they are conducting current. Power is an instantaneous product of electric potential and current: P = E x I. Power should not be confused with energy — which is an absolute quantity. Energy is the product of power and time or of how much power a circuit consumes for what time period. It is straightforward to calculate the power consumed — or dissipated — by the resistor in Figure 1: P = 1 V x 0.1 A = 0.1 W.

The basic power formula and Ohm's Law combine in numerous ways to directly calculate a basic DC unit in a single step. What if you wanted to find the resistor's power dissipation based solely on the initial information given: a 1 V battery and a 10 Ω resistor?

Instead of performing two calculations by first finding the current and then the power, you could substitute Ohm's Law for the missing intermediate variable: current. Ohm's Law can be re-expressed to find current by dividing both sides by resistance: E/R = I.

We can now substitute E/R in place of I in the power formula: $P = E \times I = E \times E / R = E^2 / R$. Therefore, $P = (1\ V)^2 / 10\ \Omega = 0.1\ W$. We arrive at the same answer without first calculating current.

Figure 3 makes solving for any unknown unit as easy as a chart lookup. To use the chart, first locate the unknown property in the inner circle. If you are solving for power, select the "P" quadrant. Then pick the appropriate slice in that quadrant that contains the information you already know.

Borrowing from the previous example, we would select the formula E^2 / R because we know voltage and resistance, but not the current through the circuit. The basic units wheel allows you to quickly determine voltage, current, resistance, or power given only two of the other three units.

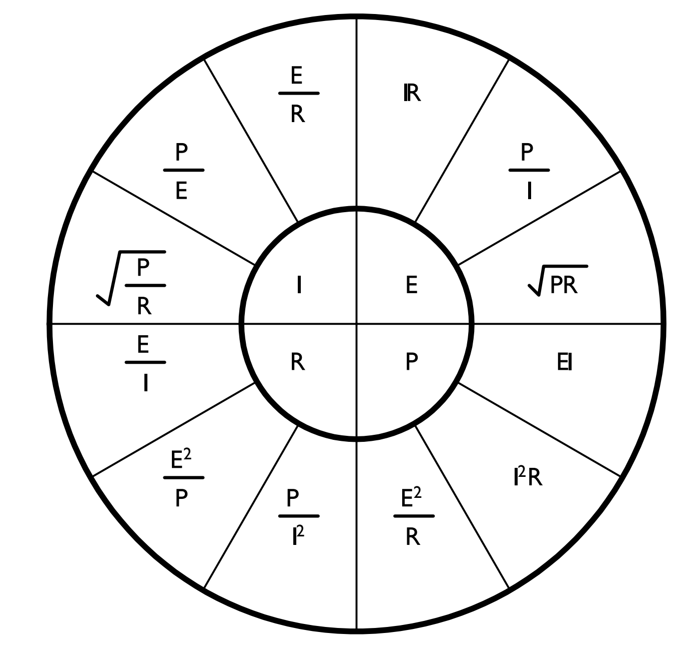
Skipping the current calculation may not really save you time in a simple example, yet time can be saved as the intermediate calculation gets more complex with more involved circuits.

Foundations for Circuit Design

To avoid potentially dangerous overheating, you should always verify that an electrical component is not forced to handle more power than its ratings specify. If you work with transistors and integrated circuits, Ohm's Law will help you select resistor values that allow adequate current flow, yet do not stress the silicon components beyond their specifications.

Understanding basic units, Ohm's Law, and the power relationship will help you with basic circuit design and prepare you to tackle more advanced circuit analysis topics. **NV**

Figure 3. The basic units wheel.



About the Author

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high-tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design, Mark has actively participated in industry standards committees and has presented work at technical conferences. He holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at mark@complete digitaldesign.com.

Go to www.nutsvolts.com — click Electro-Net

Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

A Little Bit of Everything!

This month, I would like to take a few words to update everyone on the progress of some of my other projects, tease you with some new ones, talk about some things that don't warrant a whole article, and talk a little philosophically.

HoverBot

To begin, my four propeller Draganfly clone — the HoverBot — caused quite a stir. I have received Emails from no less than 30 people who have endeavored to build their own or had already been building their own. While HoverBot has met a terrible fate at the hands of an overly zealous cleaning crew, many of you have had exciting — or at least interesting — progress that I would like to take a moment to share.

One gentleman who contacted me is building an exact clone of mine, with the exception of the shape of the plastic parts for the chassis — same GWS motors, propellers, goals for sensors, and even the same IsoPOD. You name it — a clone of a clone. The interesting thing is that our development cycle was roughly concurrent, which means he started before the HoverBot article came out. That's very quirky, like concurrent evolution.

Another fellow is building a miniature version of what I built, with the sides of yogurt containers cut out and built into propellers, but the most impressive one by far is the gentleman who has taken it upon himself to utilize automotive fan motors, PVC sprinkler pipe, and motorcycle batteries. I do not have the highest of hopes for his success — due in large part to his insistence in using the most inefficient materials and components. In fact, I have many concerns for his safety and the safety of his loved ones, but I must appreciate the fact that he is willing to try such a grandiose project.

Build Stuff

My recent article, "Build Stuff," was a little unbalanced. It didn't leave me with enough "meat" to allow me to write a full follow-up article. I do have some pictures I would like to share with you of a robot I am building with the techniques detailed there and hope they inspire you to build something and to overcome your fear of tools.

Construction on this was really easy, once I got started. I wanted to play with something that could do similar things to synchro-drive moves, but without the complexity. The drive mechanism, shown in Figures 1-3, is simply two servos — one hacked for continuous rotation and the other not.

The key elements here are the use of adhesives to bond my polystyrene structure together and the use of fasteners and foam tape to hold the structure to the components. It is also worth noting that my servo horns matched up almost perfectly with my nifty Tamiya tires.

It had been awhile since I had built something using this technique and I really had forgotten how quickly you can build up something. Then I remembered my robot, Tripe Odd?, which was built using similar techniques. You can see nice pictures at **http://robots.net/robomenu/1024616002.html** Tripe Odd? uses nine servos: three per leg, withthree legs total. Tripe Odd? was built up in a few hours and was the net result of having nine servos, an old Apple AirPort case,

Figures 1, 2, and 3. Multiple views of construction techniques in action from last month's column.

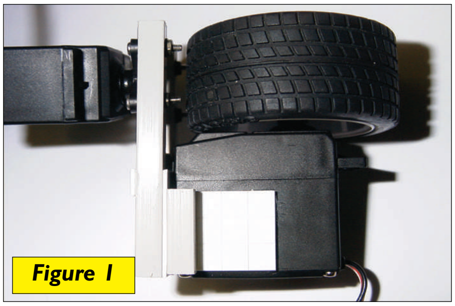


Figure 1

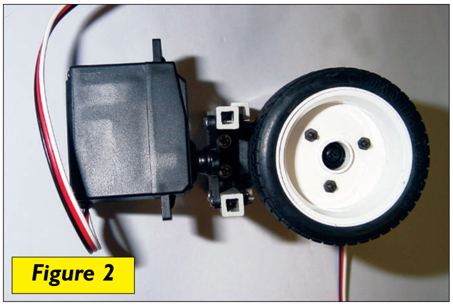


Figure 2

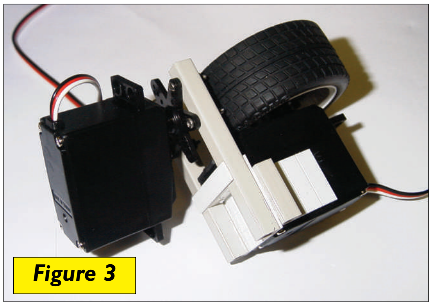


Figure 3

and a few hours of free time.

Tripod worked okay — not great — but, after burning up a knee servo doing what amounts to robotic Tai Chi, I shelved her for a rainy day. The chassis was too heavy for the legs, but it was one of those "had to be done" things. It just looks so cool!

Waxing Philosophic

This brings me to something that I wanted to discuss, but I didn't feel it warranted 2,000 words over four pages. It is all about experimentation and fun.

My little three-legged robot was built out of my desire to diverge from bilateral symmetry and explore unique geometries. It also brings up a lesson or two. Don't be afraid to try and don't be afraid to play. Many people have asked me how I learned all this stuff and my answer was just that — playing and experimentation.

My real experiences in robotics go back to when I was six — yes, six. My parents had allowed me to use knives, soldering irons, and hand tools at four and I had always wanted to build a maze follower. I got some small wheels, PCB material, and resistors and soldered and glued the thing together. That is where I got stuck. Motors would have helped, as well as an understanding of what to do with the resistors. It didn't function, obviously, but at least I had identified some important construction details and components.

My first real mobile robot didn't have a real processor as you would know it. It was literally a bunch of 555 timers, a few transistors, two photo resistors, a relay, and two R/C servos. The servo was driven to neutral position by two 555s with the photo resistors replacing the servo's feedback potentiometer. It rolled around, seeking the dark until it bumped something; then, a 555 would hold a relay closed, reversing its drive motor, biasing the steering servo to the right, opening the relay, and then proceeding as before. It literally took months of work, but it did finally work and it captivated me forever.

From there, I moved on to projects with real processors, using my employer's requirements as a springboard.

To cite a few examples, my first microcontroller motor control project was built on a 68HC11 microcontroller, A/D converter card, and motor control card from New Micros, Inc. Its function was simply to rotate a camera on its optical axis.

I told my boss I was in over my head, but I would give it a shot. The development went very well, but I got there by getting a second microcontroller card to play with at home. Once at home, I played with blinky lights and push buttons and it gave me a real sense of programming,

Figure 4. Phil Cox's "Shelob," a 4 DOF walker, soon to be an open source project.

without having to worry about anything except pure programming or achieving usable results.

My second project — one that helped me win one of my industry's highest accolades — was built much the same way. It was required to be small, so I investigated the industry and found the Domino from MicroMint and the BASIC Stamp from Parallax. I chose the Stamp and, again, bought an extra one to play with.

By this time, I had a feeling for some of the different embedded controllers of the time and knew how to apply them. If I wanted speed and floating-point support, I couldn't beat my 68HC11 and, if I wanted flexible pin assignments and a small size, a Stamp was a good way to go. Both are useful for certain things.

Now, I work with embedded processors, from PICs to Pentiums. I deal with encoders and motors; I try to choose the right hardware and software for the task at hand. Always remember, only through experimentation and play can you really learn something.

Engineer an Ecosystem

On the subject of learning, I am looking for people that might want to corroborate on articles or at least give me guidance. I am embarking on some advanced projects, but my weak suit is programming and I am looking to bolster my abilities there.

I would like to understand genetic programming and neural networks better. I grasp the basic concepts, but — until I find an application I understand — I can't get my hands around the finer details. I do have a couple of projects in mind, but I am interested in finding people to corroborate with.

I am considering modeling an ecosystem, with both virtual and "real" aspects. In this ecosystem, the majority of learning would be done virtually, with the virtual creatures whose behavior showed the highest "fitness" would then be modeled with real robots for demonstration purposes.

I imagine some sort of fusion, with the basic "neural" architecture laid out — or perhaps modular building blocks of neurons with a genetic algorithm to determine the weights of the neurons and even the architecture of the neural net itself.

The creatures I envision inhabiting the "real" world would be your typical two-wheelers and a caster arrangement with a complicated "digestive system." Food would be represented by colored disks, with the primary colors — red, green, and blue — representing different nutritional content. Red would represent protein, blue would be "slow energy," and green would be "fast energy." The opposite side of these disks would be colored in dark hues and would also represent nutritional content.

The robots — which I call turtles and shrimp — roam about, pick up these colored disks, and store them on a vertical disk arrangement for later deposition in an orientation opposite of how they were found. The turtles would favor the brightly colored disks — representing plants and animals — and the product left unused by the turtles — represented on the opposite side of the disk — would be favored by the shrimp. While the turtles would be the consumers,

Figure 5. Lynxmotion's Hex 3-R.

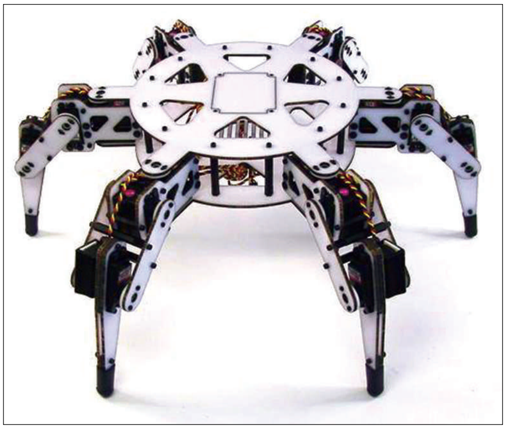
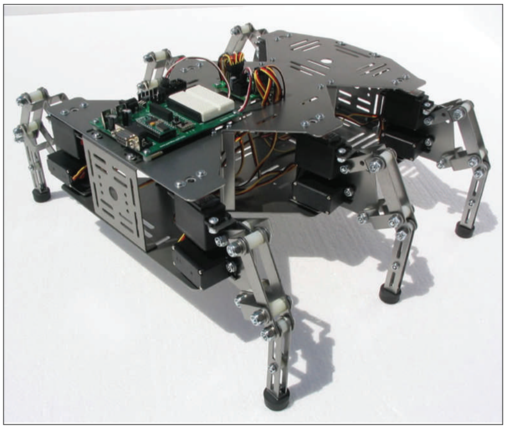


Figure 6. CrustCrawler's HexCrawler.



the shrimp would be a rejuvenating force — a sort of Gaia.

I envision the little creatures learning that certain characteristics of the food must be utilized properly or they will become unfit. Imagine that a lack of protein, as well as age, affects the speed of the motors, efficiency of the use of virtual energy, and range and accuracy of the sensors. Fast energy, if not immediately used, will become virtual fat, which will cause a slowness of the virtual creature's metabolism. Interaction between creatures will be interesting, perhaps even forming a sort of symbiotic economy.

Robo Round Up

Another thing on my heaping plate of robot stuff is my six-legged robotic round up — a sort of hexapod hoedown. I recently purchased a new H3-R from Lynxmotion and the folks from Parallax are sending me a HexCrawler from CrustCrawler, as well. To top this off, a friend of mine has a really cool hexapod called Shelob that I will be showing off, as well. Shelob is special in that it will be an "open source" project. If you are interested in contributing to Shelob, feel free to contact me.

The interesting features here are the number of joints per leg. HexCrawler — with two joints per leg — is what I call a 2 x 6. This affords the easiest programming, but with the least sophistication.

Shelob, in contrast, is a 4 x 6. This offers more control of the angle of attack of each leg and, in addition, Shelob has an articulated body, much like my centipede robot.

Somewhere in the middle is the Hex 3-R from Lynxmotion. Hex-3-R is a 3 x 6 with a symmetrical geometry. This will be an interesting challenge in that, with the other hexapods, there is a distinctive bisection line. The legs on one side behave similarly to each other and somewhat opposite of those on the opposing side.

With this symmetrical geometry, it is almost "every leg for itself." Also, with a 3 x 6 geometry, you get into the realm where inverse kinematics are useful if you happen to have a spherical tip on the leg, as does the Hex 3-R.

There are many levels to hexapod walking, from "pre-canned" gaits that are useless on any surface that isn't perfectly flat, to deterministic walking, where the robot reacts to the terrain and acts and reacts accordingly.

Somewhere in between are inverse kinematics, sensors, and multiple layers of behavior that I hope to explore. In particular, I am looking toward the works of Porta and Celaya for guidance in the fields of control and navigation.

Coming Soon ...

To top things off, I hope to cover simulating robotics and interfacing on desktop PCs sometime in the near future, utilizing easy-to-use languages. I have gotten my hands on a copy of DarkBasic Professional as well as Blitz3D. DBP and B3D are both basic programming "wrappers" for many of the user interface and graphics functions that could be really fun to play with, if they weren't so difficult.

Now, before you start judging me, heckling me to use Java or C++, consider all the difficulties associated with just the integrated development environments of Java and C++. In the same time that it took to install either of these software packages, I was whirling and twirling graphical objects with ease. I wrote a simple MP3 player in DarkBasic, for instance. Granted, I do not have access to the entire Windows library of functions, but I can get cool results quickly.

Both languages can handle external DLL libraries if I really need to have them. If that is the case, I can trade some Futaba servos or beaver pelts with a friendly programmer and have him "wrap" the functions I need, but, in the meantime, I am able to do basic stuff in BASIC, quickly and easily. Before anyone rushes out to buy one or the other, be cautious. I bought B3D with a book from a site other than Blitz research. If you do so, you may have a hideous time getting a registration from them.

My first impressions are that DBP is more powerful, faster, and younger in its development, while B3D appears to be less powerful, but more stable.

My final goal here is to be able to simulate legs and behavior, implement the knowledge I gain on real hardware, and to finally build cool PC-based interfaces to that hardware via wireless and be able to monitor and control the robot remotely.

Again, I extend an open invitation to you to share with me if you are using either of these products, particularly if you have had success utilizing third party DLLs to interface to the serial port. **NV**

Resources

Tamiya — **www.tamiyausa.com**
New Micros, Inc. — **www.newmicros.com**
MicroMint — **www.micromint.com**
Parallax — **www.parallax.com**
Motorola (68HC11) — **www.mot-sps.com**
Lynxmotion — **www.lynxmotion.com**
CrustCrawler — **www.crustcrawler.com**
DarkBasic Professional — **http://darkbasic.thegamecreators.com**
Blitz3D — **www.blitzbasic.com**

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Identifying Bad Ideas

New ideas abound, but it's important to be able to recognize bad ideas, as well as good ones. Good ideas can make lots of money. However, it's probably more important to be able to see bad ideas from the start. These bad ideas may very well cause problems in the future from lost sales, lawsuits, and wasted time and money.

Other People's Ideas

It's always easier to examine someone else's idea, rather than your own. You can be more objective and objectivity is a critical factor in judgement. There are some people who suggest that figuring out if an idea is good or bad requires a level of expertise equal or superior to the person presenting it. This is called peer review. It is certainly true that training and experience can help. After all, it's difficult to know if a new method of measuring the gravitational constant really is good or bad if you don't know anything about it. This suggests that the highest levels of research cannot be judged. Truthfully, there are those at that level who firmly believe this.

It seems to me, though, that logic, reason, and common sense are often sufficient for those ideas that we may have some familiarity with. Therefore, we don't always have to be an aerospace engineer to see a bad idea in an aircraft. Let's look at a real example.

Suppose you want to vary the angle of an aircraft control surface (wing or stabilizer). Would you put the pivot point close to the leading edge (front) or trailing edge (back)? Why? If you are like most engineers, a little thought suggests that the pivot point should be near the front for safety reasons. Think about what would happen if the control surface adjustment mechanism should fail. If the pivot point is in the front, the rushing air would force the control surface into a neutral position. However, if the pivot point was toward the back, the rushing air would force the control surface to one extreme or the other. (Try it. Hold a piece of paper at the leading edge and blow into it. Now do the same, but hold the trailing edge.)

On January 31, 2000 Alaska Airlines Flight 261 fell from the sky and killed all 88 people on board. The jackscrew that controlled the angle of the rear horizontal stabilizer failed. This stabilizer had a pivot point near the trailing edge. The result was that the aircraft ceased to be airworthy when the control surface failed and forced the plane to dive.

That was a bad idea. However, it is important to realize that a bad idea does not necessarily mean a bad design. Sometimes, a compromise is required. The decision to use a bad idea may be for other engineering or financial reasons. However, it is crucial to see this as a significant weakness and compensate for it. It appears that the real cause of the failure of the jackscrew was that proper maintenance was not performed. It apparently failed because of lack of grease. (Cutting back on maintenance to save money is also a bad idea.)

There are a number of points here. If you understand the fundamental principles and the concept of the idea, you can usually see if it's good or bad. A bad idea can still be used successfully if its weaknesses are addressed. The Boeing MD-80 is a sound airplane and has a very good flight record. However, bad ideas will always be dangerous.

Ideas Come From a Person

A single person creates an idea. It may be refined by others, but all ideas come from a single individual. Someone had the idea to put the pivot point toward the trailing edge in the example above. I'm sure there were reasons for that choice. Hopefully, those reasons were important enough to outweigh potential problems. Those reasons will probably not be known by the general public. So, we cannot judge if the bad idea was offset by other necessities.

Bad ideas will occur in any engineer's career. Whether they are your own or someone else's, it is important that they be recognized and dealt with. Every engineer should be prepared and understand how to cope with them. The situation will arise where you will be directed to develop a bad idea. It's only a matter of time. How you handle this situation is important to your career.

Remember that the idea came from a person. This means that the person has a personal — as well as a professional — stake in it. Usually, the personal attachment to an idea will be strong. It's just human nature. Unfortunately, this makes criticism of the idea feel like criticism of the person. Try to find out who that person is. You may want to talk to him or her to determine how the idea was developed. Look for the reasons

behind the idea. It may be that a bad idea is the only idea that can work.

Don't criticize the idea at this meeting. It will probably alienate the person and make future interactions difficult. (An exception to this is if you know each other well. In this case, you can probably voice your concerns directly.) However, you could say something fairly neutral like, "I'm concerned about failure modes. Have you looked at what might happen if part XYZ fails?" The person's response may help you determine how to proceed. "I don't know." "I didn't think about it." "I considered it in detail and here are my conclusions." "It's not important." "Why are you asking?" These responses should tell you a lot about the person and his thinking.

Once you have collected as much information as you can about the person, idea, and development process, evaluate it privately. Do so carefully and thoroughly. It may turn out that you agree that the idea is the only viable option. It's only a problem if you don't agree.

Fixing a Bad Idea

The first thing to do is to be sure that you fully understand the idea. This means knowing about the principles, as well as the approach. If you don't, you can't be sure you're correct. In either event, it's probably best to find a third person to discuss it with. This person should be someone who has no personal or professional interest in the idea. (This may not always be possible.)

Don't try to convince or argue with this person. Just present the facts and your concerns. Be articulate. If you cannot describe your position to a neutral third party well enough for comprehension, you'll never succeed in changing the bad idea. Ideas are both fragile and tenacious. They can be easily ruined at their conception, but, once rooted in someone's mind, they have a life of their own. This is especially true if that someone has significant authority.

Ask this third person for an opinion and listen closely to what is said. If this person disagrees with you, you have a problem. Find out precisely why. Go back and study the situation carefully. Either you missed something or else you failed to communicate. You can't expect to get anywhere unless this problem is fixed.

If the person agrees with you, you also have a problem. What do you really want to do? Whistle blowers and nay sayers are rarely appreciated. So, always try to keep your concerns focused and off the record. Determine if the third person is willing to support you. Two people saying the same thing have much more weight than a single person (read "disgruntled employee").

Be scrupulously precise in anything you say. Be absolutely sure that the third person agrees with what you express before saying so. Never send out any memo saying, "Bob agrees with this," unless you've shown Bob the memo. There's nothing more devastating than Bob replying to his superiors, "I never said that."

Have a Better Idea in Hand

Many times, bad ideas are presented simply because someone isn't thinking. Think for them. Figure out a better way to do the same thing. Preferably, it should be clearly better. Then, when someone says, "What else can we do?" you have the answer. This technique of "improvement" can be very effective. It shows several things: First, that you are thinking (which, unfortunately, is not all that common). Second, it shows that you are concerned for the welfare of the project/company. Third, you are providing an idea that has merit (another rarity). Lastly, you give people a choice. People — especially managers and superiors — like choosing. They feel that they are doing their job if they make a choice. Just be sure the choice is a no-brainer. (Place your own "no-brainer" and "boss" joke here.)

Your Own Ideas

This brings us to examining your own ideas. My first bad idea (that I remember) was when I was about five or six. My brother (two years older) and I were playing with a hobby motor and some batteries. We discovered that the motor went faster with more batteries. Unfortunately, the leads on the motor were too short for more than three batteries.

Where could we find lots of power where the terminals were close together? Of course — the wall socket provided just that! That should make the motor turn really fast. My brother said it wouldn't work, but that was no obstacle. He was always negative regarding my ideas. Carefully holding the wires by the insulation (I wasn't completely stupid!), I pushed the leads into the outlet. There was a flash, a bang, and some smoke — and a dead motor.

Unfortunately, many adults pursue their ideas in a similar fashion. They get excited, stop thinking, ignore peers, and rush dead ahead. To be really effective in spotting your own bad ideas, you must divorce feelings from your analysis. This is hard to do. Again, it's just human nature. Probably the best approach is to go slowly. Fully understand the topic and analyze it in detail. Don't gloss over things. Look at what every part of the idea implies. Don't expect that problems will take care of themselves; they never do. Remember that the only time someone else will examine your idea will be to find fault with it. Isn't it better to correct the fault before that? Alternately, if the faults are not fixable, you could choose not to present the idea at all. You don't want to look silly, do you? If you haven't noticed, we've changed the topic slightly. Now, we're talking about how to make good ideas. To mangle Sir Arthur Conan Doyle (Sherlock Holmes), "Once you've eliminated the rotten, whatever's left must be good." A refined idea is one that has the bad parts recognized and removed or fixed. Refined ideas are usually workable ideas and are more easily recognized as such.

If you've ever been privy to a discussion on some idea, you know, "It's well thought-out," carries a lot of weight. Conversely, "It's ill conceived," is a very bad comment. It's important to remember that a good and workable idea may have bad parts. It's just that the bad parts have been recognized, addressed, and compensated for.

Finding the Bad Parts

You probably already know that new ideas are often treated as bad ones. This is because people dislike change. "We've always done it this way. Why change now?" is a standard phrase that must be addressed. More to the point, it must be addressed in terms that those people understand and value. Show how it will save time or money. Show that it will improve reliability or increase sales.

Another, somewhat similar problem is the "not invented here" response. This is generally simple ignorance about other methods already developed to solve a problem. People (and companies) like to use ideas they have created. It's human nature (and corporate nature) to be proud of research and development performed in-house. So, if you want to digitize a procedure that has been developed from scratch with analog techniques, it's a bad idea. As above, you must address this in terms that others will understand and appreciate. These points may seem fairly obvious — they are. However, this is the same technique used to find the bad parts of *your* idea. Look at your idea from someone else's point of view. If you can do this, it removes the emotional connection to it and allows you to be objective.

As we said before, being objective is a critical factor. Apply the "not invented here" concept to your idea. Are there new or existing techniques that can improve it? Are you holding on to that part because of pride? Don't be afraid to change your idea. Ideas are not fixed. They're alive. They grow and develop. If you are determined not to change your idea, then you have the same, "We've always done it that way. Why change now?" attitude noted above. Those human factors you need to address in others are the same factors you must address in yourself. If you can't do this, you won't find the bad parts.

Practice Helps

The more prolific you are with ideas the better they will become. As in any other endeavor, the more you practice, the more you improve. It can be helpful just to sit and think up new ways to do things. Then, pick out the best one. By picking one, you learn not only to judge good from bad but you also help to separate personal attachment to them. You become more objective. The more ideas you have, the more likely it is that some will be good.

Testing ideas also identifies bad ones. Those simply don't work. But you often learn something from them anyway. Any learning is always useful. Learning what doesn't work can extremely important. There is some truth to the statement that the more you fail, the more you learn. Testing also gives you hands-on experience. There is no substitute for this valuable knowledge. Finally, if the test does work, the idea must be good. So, now you have a good idea and a test to support the claim. As we said before, eliminating the bad leaves the good.

General Bad Ideas

Any idea that requires a change to infrastructure is bad from a practical standpoint. It may be useful and important, but it has very little chance of success. Let's look at a few examples.

The hydrogen-powered car is a bad idea. It's important and useful, but is most likely doomed because of infrastructure. Before any consumer will buy a hydrogen-powered car, there must be hydrogen filling stations on every corner. There must be hydrogen pipelines or transport mechanisms in place to move hydrogen across the nation. There must be hydrogen production plants capable of providing the vast quantities of fuel needed.

It will take untold billions of dollars of investment in infrastructure before any cars will leave the showroom. Would you buy a car that can't be easily refueled? Will the citizens support the taxes needed to build the infrastructure? Will the oil companies sit idle while this happens?

The Segway Human Transporter (the motorized, two-wheeled personal vehicle with the long handle) is a bad idea. It's doomed as a mass market item because of infrastructure. In particular, city laws. In virtually every city, it's illegal to use a motorized vehicle on the sidewalk. With a top speed of 12 mph, very few people would dare to use it on a city street. (Bicycles cruise at 10 to 15 mph, and can reach speeds of up to 25 to 30 mph.) City use is virtually a requirement with a maximum range of 10 miles per charge.

In order for the average person to choose a $4,000.00 Segway over a $1,000.00 Mo-Ped, a $400.00 bicycle, or a $40.00 pair of in-line skates, laws will have to be changed. That's not

likely. It's doubtful that people will accept motorized vehicles running over their toes on the sidewalk. Politicians won't risk alienating lots of voters for the few who own Segways.

Teletext or anything that uses the TV for something other than games or video entertainment is a bad idea. Since the mid 1980s, attempts have been made to use the TV as an interface to the Internet (in some form). The first was "Teletext," which provided shopping and bill paying through the TV. Never heard of it? That shows how good it was.

Currently, Microsoft is trying a similar thing. It has been marketing a box that allows you to use your TV for Email and Internet access. The problem is social infrastructure or human nature. Americans simply don't like using their TV for that. If they want to surf the net, they get a computer. Note: Microsoft may be using this as a "loss-leader" to attract computer-phobes and steer them into buying computers. They may be successful in that, but it will never be a popular commercial item.

Ethics

What do you do if you are told to develop a bad idea by your boss? Obviously, that's up to you. If you're working on a Segway-type of product, there probably isn't much of an ethical problem. If it's a safety-related product — like the MD-80 horizontal stabilizer — it could very well be something to be concerned about.

Depending on your level of involvement, you might talk to your boss, write a letter to your boss or to management, ask to be transferred, or quit. Before you do anything, you should have a long discussion about it with someone who can understand your problem. Never do anything too hasty, unless you are willing to live with the fallout that is likely to happen.

This brings us back to the topic of communication. Good ideas, bad ideas, and criticism all require communication. Being articulate is crucial for this. You must be able to tell others exactly what is in your head. Otherwise, they will get the wrong idea. That will not be helpful. Only proper communication can clarify concepts so everyone can understand them.

Conclusion

Bad ideas can be identified with some thought and experience. A good product may have a bad idea as a part. However, this bad part must be recognized and compensated for. Removing the bad ideas can make a concept good. Finally, as in any engineering undertaking, communication is vital. Whether you are selling a good idea or criticizing a bad one, if you can't explain your thoughts, you won't succeed. **NV**

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

A hodgepodge of circuits ranging from using old Ma Bell telephones for a home intercom to thermostats for attics. A universal low battery indicator and some serious security websites.

Intrahouse Telephone Intercom

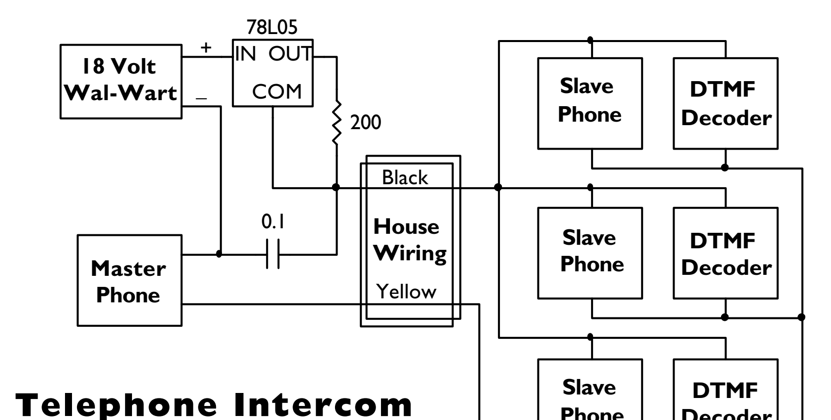
Q. How can I build a system that would plug into a standard two-line phone outlet that would allow me to use line two for an intercom throughout the house with garden-variety telephones (the $10.00 kind) that are commonly sold through places like Wal-Mart and Long's Drugs? Line one would, of course, be used for normal POTS phone calls; line two is currently unused and I'd like to tap into its wiring.

Klaus Reinoso
Miami, FL

A. Talking over the phone is easy. So easy, in fact, that all you need is a battery in series between the two. However, telephones are current operated, not voltage operated, and require a series resistor to limit the current flow. This is why I've replaced the battery with a constant current source (an LM78L05) operating at 25 mA, as shown in Figure 1. With this simple arrangement, you can have a phone at both ends and talk when both are off-hoof (receiver off the cradle). The 0.1 µF capacitor bypasses the audio around the power supply for a loud and clear connection. That's the simple part. What's harder is signaling the other end — ringing your party. The telephone company does this by putting a 90 volt, 20 Hz AC voltage across the connection. However, this is far too elaborate for something as simple as an intrahouse intercom.

Instead, I use the built-in DTMF dialer in the telephone to provide a ringer signal. All that is needed is a DTMF receiver (decoder) at the other end. Once plentiful, DTMF receiver chips are now all but obsolete. Fortunately, there still are plenty of them for sale through vendors like Futurlec (**www.futurlec.com**), B.G. Micro (800-276-2206; **www.BGmicro.com**), and JDR Microdevices (800-538-5000; **www.JDR.com**). The two chips that are readily available are the MC145436 and MT8870. A schematic for each is shown in Figures 2 and 3.

For this design, I've used the four binary output pins to signal a buzzer. For example, press the number 1 and the "Press 1" output pin of the DTMF decoder goes high and sounds the buzzer. Move S1 to the next position



Telephone Intercom

Figure 1

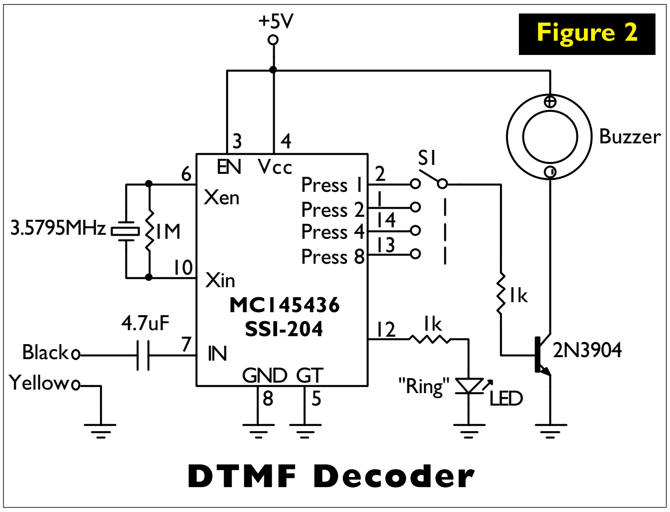


Figure 2

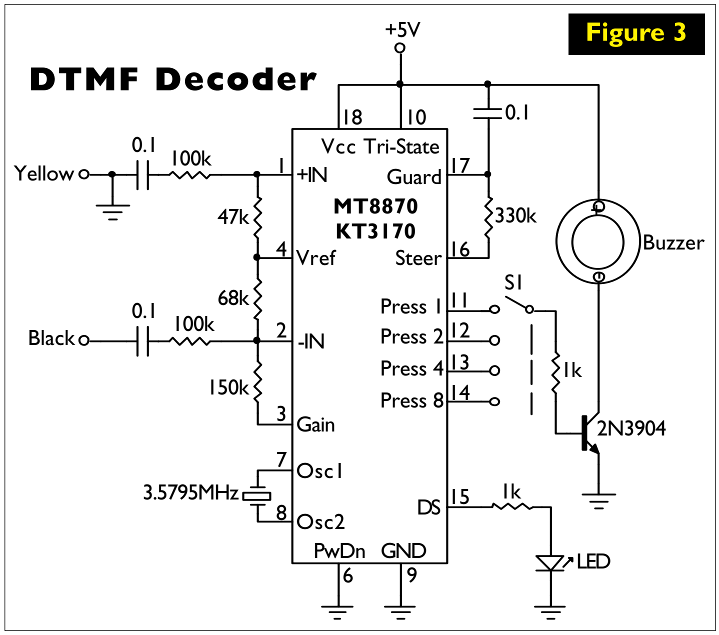


Figure 3

and pressing 2 will sound the buzzer. The same goes for numbers 4 and 8. That is, each phone can have its own unique ringer number. A single AND gate can expand the number of “phone numbers” from four to 16.

Don’t want to build the DTMF decoder from scratch? You can buy a kit from Ramsey (**www.testequipment depot.com/ramsey/kits/tt7SAVE.htm**) or Rainbow Electronic Kits (**www.rainbowkits.com/kits/TT16p.html**).

Now that we have a fully functional phone network, there’s no reason to limit ourselves to just two phones. Why not three, four, or more? No reason — except for one reservation. One phone has to be designated as the master and the rest as slaves. That’s because one slave station cannot talk to another slave station unless there is a battery in the circuit between. The only way that can happen is if the master phone is off-hook. The way to do this is ring the master, ask him to go off-hook, then ring the slave station you want to talk to. At the end of the conversation, ring the master phone and have it put on-hook. Of course, the phone company central does this automatically and, with a little thought, so can you.

Headset Mike Preamp

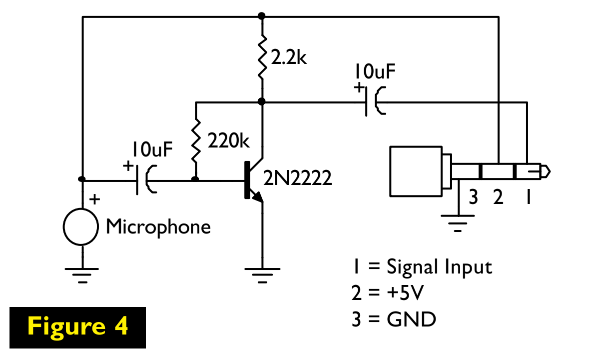
Q. In the May 2004 issue, you published the answer to my question regarding interfacing a cell phone headset to a PC sound card (“Cell Phone to PC Card Interface”). Thanks! The interface works, but the audio level from the headset microphone is a little low and needs amplification. My tests indicate about two to four times boost is needed. Do you have a simple circuit to accomplish this using the power available from the MIC input on the sound card?

Miguel Chabolla
via Internet

A. The circuit in Figure 4 should do the trick. It’s a single transistor, grounded-emitter design with a gain of about 20 dB. The parts count is low and the circuit can probably fit into your headset, if you use surface mount devices. The power comes from the PC’s MIC input jack.

Powered by Uncle Sam

Q. I have a bunch of old electric antiques and WWII surplus electronic equipment that operate on frequencies

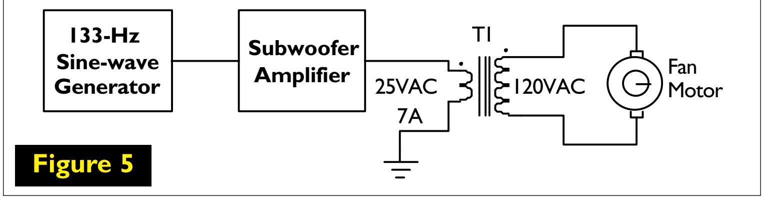


Headset Microphone Preamp

Figure 4

ranging from 133 to 400 Hz. The power requirements vary from a few watts up to maybe 200 watts and the voltages can be anywhere from 28 to 115 VAC. I'd like to build a power supply that would let me play with these treasures.

Sean M.
via Internet



120VAC, 133Hz Power Supply

Figure 5

A. Why not use the setup shown in Figure 5? The only thing you have to change is the sine wave oscillator module. For that, I'd use a function generator IC, like the ICL8038. It sells for about $3.00 and is available from Futurlec (**www.futurlec.com**).

The circuit in Figure 6 uses just a handful of resistors and a timing capacitor (C1). The output frequency varies between 112 and 454 Hz at up to 2.4 volts using the values shown. You may notice that I used fixed resistors in place of a potentiometer on pins 4 and 5, which means the harmonic distortion is 1.5% or less — plenty good enough for an AC power source. (A variable 10K pot can be used instead to further reduce the harmonic distortion.) If you wish to change the frequency range, the formula is f = 0.15/R1xC1.

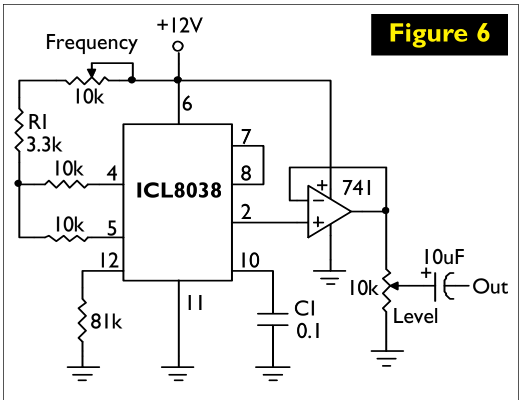


Figure 6

SineWave Generator

A Voltmeter by Any Other Name

Q. I rebuild tube amplifiers and have recently refurbished a couple of Heath W-5Ms. This model has a pair of jacks for adjusting the balance of the output tubes. Currently, I use a DVM to adjust for 0 volts, but would like to incorporate a small panel meter in its place. I have some candidates, but they are all milliamp movements. Is it possible to use one of these (zero-center scale) to measure the zero volt null?

Bruce Brown
via Internet

A. Any ammeter can be made into a voltmeter using nothing but a single resistor and Ohm's Law (Figure 7). Let's say the meter has a full scale reading of 1 milliamp (mA) and that the multiplier resistor (R1) has a value 1,000 Ω (1K). Ohm's Law says that, if you apply 1 volt across this circuit, the meter will deflect to full scale: I = E/R = 1/1,000 = 1mA. If you want to calculate the multiplier resistor for a desired voltage range, the formula is R = E/I, where E is the voltage to be measured and the I is the full-scale range of your meter. If memory serves me, the Heath W-5M had about a 1 volt range on either side of its zero balance point. This means a 1 mA meter with a 1K resistor should give you what you want. If your meter movement doesn't happen to be one

where the pointer rests at mid scale, you can modify the RadioShack 15 volt panel meter (22-410) that's based on a 1 mA meter movement. The meter has a 0 to 15 scale and comes with a 15K multiplier resistor: E = IR = .001 x 15,000 = 15 volts.

You can make it kind of a center-scale meter by prying off the plastic front and adjusting the tension spring (located behind the front panel's black adjustment screw) until the needle is about mid-scale. I usually set the pointer at 5 because it unravels the hairspring with the least stress. Change the 15K resistor to 1.8K, replace the plastic cover, and use your meter to balance the output tubes, using 5 as the zero reference. The downside is that you can no longer adjust the meter's pointer with the cover on — but once set, normally, once forgotten.

Low Battery Indicator Revisited

Q. I have a couple of questions about the "Low Battery Indicator" circuit that appeared in the February 2004 issue.

1. Will there be sufficient base drive for the 2N3906 when the output of the comparator goes low?

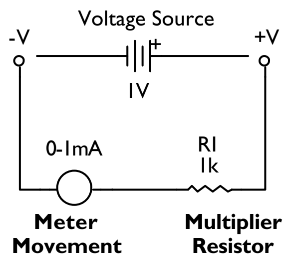
2. Assuming that there is enough base current for the 2N3906 and that the LED turns on, how is it going to turn off? What will cause it to turn back on?

Tom Gaudiello
Pottstown, PA

A. The two transistors form a relaxation oscillator (refer to Figure 8). With the comparator output high, no current can flow through R1, R2, R3, C1, or the base of Q1. At this point, Q1 is turned off, Q2 is turned off, and LED1 is off. When the comparator output goes low, the workings turn topsy-turvy. C1 starts charging through R1, R2, and R3.

When the voltage at the base of Q1 exceeds about 0.7 volts, Q1 begins to conduct and turns on Q2 — which lights LED1. It also discharges C1 through R2. The base voltage at Q1 is no longer able to sustain operation and it turns off, which turns off Q2, which turns off LED1. The process then begins all over again.

Figure 7



$$R1 = \frac{\text{Voltage Source}}{\text{Meter Current}}$$

Basic Voltmeter

Attic Fan Controller

Q. I am planning on installing an attic fan and would like to build a control that turns the fan on when it is a few degrees warmer inside the house than it is outside. I am not looking for a thermostatic switch with a set temperature, but rather a control that works on a difference of temperatures (a difference of maybe 5° or so) — regardless of the temperatures.

Calvin Hirmke
Broomfield, CO

Low-Battery Indicator

Figure 8

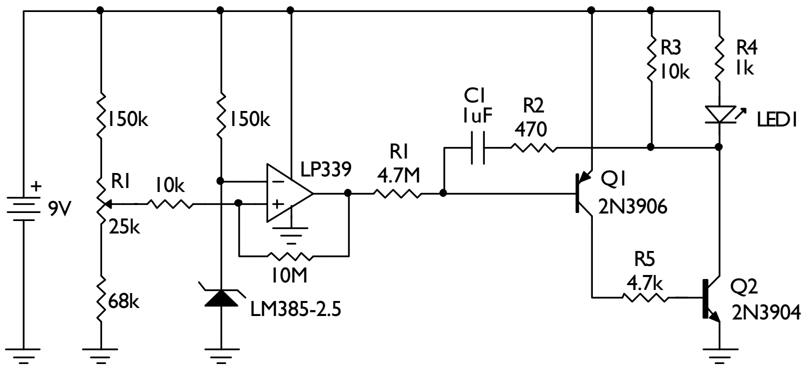
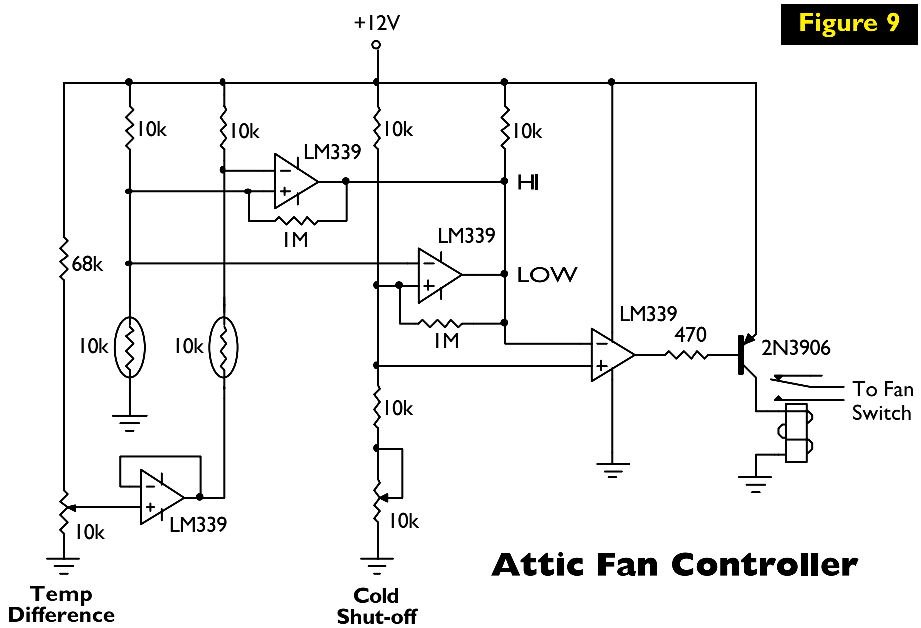


Figure 9



Attic Fan Controller

Cool Websites!

Check out these security-conscious sites:

Anti-virus software downloads from WinPlanet:
http://nl.internet.com/ct.html?rtr=on&s=1,wvm,1,9xn1,9gsc,3qmh,cu1s

Free virus scanner test from WinPlanet:
http://nl.internet.com/ct.html?rtr=on&s=1,wvm,1,kdsb,fyqw,3qmh,cu1s

Avoid identity theft.
This alert by the Federal Trade Commission tells you how:
www.ftc.gov/bcp/conline/pubs/alerts/phishingalrt.htm

A. Let's see if I got this right: No matter what the outside temperature, you want the attic fan to turn on when the attic temperature is greater than the outside temperature, right? I can understand why you want the fan to run when it's 75° outside, but do you really want it to turn on at 45° and vent out your precious indoor heat? I don't think so.

With that in mind, I came up with the following circuit (Figure 9). Viewed from afar, you can see that the two comparators are set for different trip points. Nothing is unusual there. What you don't see is the OR logic formed by the open collector outputs. This creates a window comparator. That is, the window is open for voltages between the HI and LOW set points. Anything outside this range in either direction closes the window. The TEMP DIFFERENCE pot sets the size of the window — the temperature differential.

To prevent the fan from turning on in cold weather, a third comparator is used. This time the COLD SHUT-OFF pot sets a point (voltage), below which the relay won't engage. A pair of 10K thermistors, of course, are the temperature sensors: one mounted outside and one in the attic. Both should be sheltered from air currents (wind) by placing them in an inverted plastic prescription bottle with small vent holes drilled at the top and the sbottom left open. **NV**

Resources

Futurlec — **www.futurlec.com**
B.G. Micro — **www.BGmicro.com**
JDR Microdevices — **www.JDR.com**
Ramsey — **www.testequipmentdepot.com/ramsey/**
Rainbow Electronic Kits — **www.rainbowkits.com**
National Semiconductor —**www.national.com**
American Science & Surplus — **www.sciplus.com**
RadioShack — **www.radioshack.com**

1-800-446-2295

AM-FM BROADCASTERS, CAMERAS, TRANSMITTERS HOBBY KITS, AMATEUR RADIO, TOOLS...AND MORE!

ramseykits.com

Professional FM Stereo Radio Station

- ✔ Synthesized 88-108 MHz with no drift
- ✔ Built-in mixer - 2 line inputs, 1 mic input
- ✔ Line level monitor output
- ✔ High power version available for export use

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

FM100B	**Super-Pro FM Stereo Radio Station Kit**	**$269.95**
FM100BEX	**1 Watt, Export Version, Kit**	**$349.95**
FM100BWT	**1 Watt, Export Version, Wired & Tested**	**$429.95**

Professional 40 Watt Power Amplifier

- ✔ Frequency range 87.5 to 108 MHz
- ✔ Variable 1 to 40 watt power output
- ✔ Selectable 1W or 5W drive

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 30 watts! And this is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

PA100	**40 Watt FM Power Amplifier, Assembled & Tested**	**$599.95**

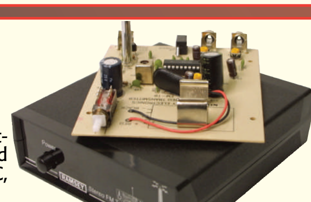
Synthesized Stereo FM Transmitter

- ✔ Fully synthesized 88-108 MHz for no drift
- ✔ Line level inputs and output
- ✔ All new design, using SMT technology

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	**$139.95**

Tunable FM Stereo Transmitter



- ✔ Tunable throughout the FM band, 88-108 MHz
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	**$44.95**
FMAC	**110VAC Power Supply for FM10A**	**$9.95**

Professional Synthesized AM Transmitter

- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	**Professional Synthesized AM Transmitter Kit**	**$99.95**

Tunable AM Transmitter

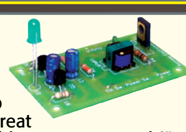
- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connector

A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	**Tunable AM Radio Transmitter Kit**	**$34.95**
AC125	**110VAC Power Supply for AM1**	**$9.95**

Mini-Kits... The Building Blocks!

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

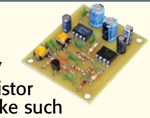
TS4	**Tickle Stick Kit**	**$12.95**

Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9	**Super Snoop Amp Kit**	**$9.95**

Dripping Faucet



Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

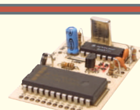
EDF1	**Dripping Faucet Kit**	**$9.95**

LED Blinky

Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1	**LED Blinky Kit**	**$7.95**

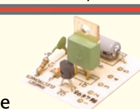
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7	**DTMF Decoder Kit**	**$24.95**

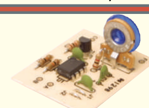
Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3	**Electronic Siren Kit**	**$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5	**Universal Timer Kit**	**$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1	**Voice Switch Kit**	**$9.95**

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1	**Encoder/Decoder Kit**	**$9.95**

RF Preamplifier

Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

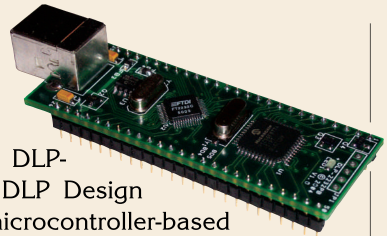
SA7	**RF Preamp Kit**	**$19.95**

Touch Switch

Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1	**Touch Switch Kit**	**$9.95**

SECOND GENERATION DLP-2232PB



The second-generation DLP-2232PB — new from DLP Design Inc. — is a cost-effective, microcontroller-based module designed to make easy work of interfacing an electronic peripheral to a host computer via USB.

The DLP-2232PB combines FTDI's third-generation FT2232C dual-channel USB IC with a Microchip PIC16F877A microcontroller in a standard 50-pin, 0.9 inch footprint to form a rapid development tool. The 16F877A microcontroller comes preprogrammed with basic functionality for port-pin access via USB and can be reprogrammed (if desired) via an onboard USB interface with no external device programmer required! Microcontroller programming is performed via the second USB channel in the FT2232C. The DLP-2232PB was developed for engineers and hobbyists seeking simplistic USB prototype development for devices such as ISDN and ADSL modems, digital camera and MP3 interfaces, high speed USB instrumentation, test equipment, etc.

Data can be sent/received via USB to/from a host PC or Mac at up to 2 megabits per second. There are 16 I/O lines (five can be configured as analog inputs) plus an eight-bit data bus and four additional general purpose I/O lines from the FT2232C USB IC available for interfacing to user electronics. For a list of worldwide retailers, click on **www.dlpdesign.com/usb/dist.html**

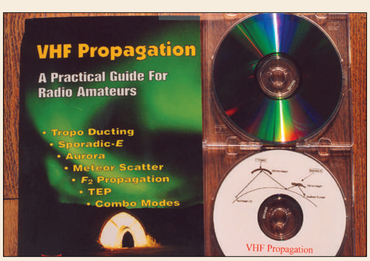
For more information, contact:

DLP DESIGN, INC.
Tel: **469-964-8027**
Email: **sales@dlpdesign.com**
Web: **www.dlpdesign.com**

Circle #31 on the Reader Service Card.

VHF/UHF PROPAGATION BOOK AND AUDIO CD

Well known VHFers Gordon West and Ken Neubeck announce the publication of their new book — *VHF Propagation, a Practical Guide for Radio Amateurs* — with over 125 pages of radio excitement on the VHF and UHF bands. The book covers: atmospheric anomalies, tropospheric ducting, sporadic E, aurora, meteor scatter, moon bounce, satellites, F-layer single and double hops, sounds of the ionosphere, six-meter FM skywaves, and trans equatorial propagation.



Both authors realize the need for a VHF/UHF propagation book without the endless pages of ultra-technical refractive index formulas and meaningless charts containing nothing but numbers. This book is still plenty technical, but it is written in terms of logical amateur radio operation. The book is published by CQ Communications, Inc., and may be ordered by calling their toll free number with your credit card. Price is $15.95.

Gordon West has also recorded a companion audio CD (or cassette) bringing each of these propagation sounds to your stereo, along with West's narration. Listen to spherics at 30 Hz and pick out the sounds of CW coming in on 432 MHz 2,500 miles away via tropospheric ducting. Hear what moon bounce sounds like and listen to the fascinating sounds of VHF/UHF auroral propagation.

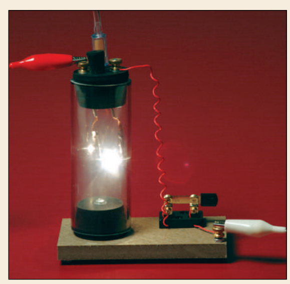
The disk (or cassette) and book are available for $20.00, plus $4.00 shipping (personal check only). To learn more about the book and/or the audio VHF/UHF propagation program, call Gordon West directly M–Th 10:00 am to 4:00 pm, Western time zone.

For more information, contact:

GORDON WEST RADIO SCHOOL
2414 College Drive
Costa Mesa, Ca 92626
Tel: **714-549-5000**
or contact CQ Communications, Inc., toll free
Tel: **800-853-9797**

Circle #58 on the Reader Service Card.

REINVENTING EDISON — BUILD YOUR OWN LIGHT BULB KIT



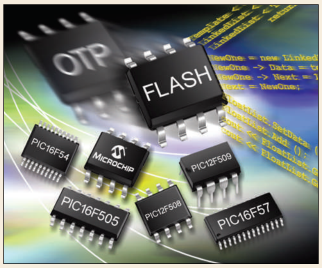
Retrace the steps of Edison and other inventors as you build a working light bulb using the filament materials of your choice. Learn about electricity, light, properties of matter, energy, and the scientific method. Test the effects of vacuum on the life of your bulb. Perform interesting experiments with #30825-63 — Reinventing Edison, Build Your Own Light Bulb Kit for $55.00.

For more information, contact:

SCIENTIFICS®
Dept. A041-C999
60 Pearce Ave.
Tonawanda, NY 14150
716-874-9091 or **800-728-6999**
Fax: **800-828-3299**
Email: **cons_order@edsci.com**
Web: **www.ScientificsOnline.com**

Circle #40 on the Reader Service Card.

NEW 8-BIT FLASH PIC® MICROCONTROLLERS



Microchip Technology, Inc., announced five new PIC® eight-bit flash microcontrollers that provide program-memory updates to its most popular Baseline one-time programmable (OTP) microcontrollers.

The new PIC16F54, PIC16F57, PIC16F505, PIC12F508, and PIC12F509 offer customers the benefits of reprogrammable flash memory via an easy migration path from Microchip's existing OTP devices, with equivalent price points and identical pin counts in 8-, 14-, 18-, 20-, and 28-pin packages. Additional enhanced features on these new microcontrollers include an improved internal oscillator, wider operating voltage of 2–5.5 V, improved reset functionality, and smaller (MSOP) packaging for the PIC12F508 and PIC12F509.

Other significant features of these new Baseline PIC microcontrollers include: standard flash program memory, 4 MHz internal oscillator, baseline 12-bit core with 33 instructions and two stack levels, 25 mA source/sink current I/O, low power (100 nA) sleep current, one eight-bit timer (TMR0), watchdog timer (WDT), in-circuit serial programming™ (ICSP) capability, power-on reset, and power saving sleep mode.

All five devices are available for sampling and volume production is planned for August. Microchip's MPLAB® development tools will support these microcontrollers.

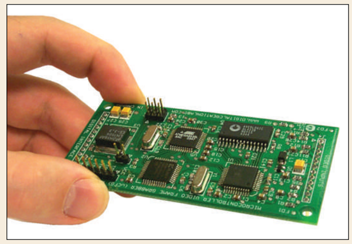
For more information, contact:

MICROCHIP TECHNOLOGY, INC.
Tel: **888-MCU-MCHP**
Web: **www.microchip.com**

Circle #87 on the Reader Service Card.

NTSC/PAL VIDEO FRAME GRABBER WITH SERIAL INTERFACE

The new Microcontroller Frame Grabber (µCFG) from Digital Creation Labs Inc., is a compact plug-in OEM frame grabber module with a simple TTL-level serial interface and ASCII command set.

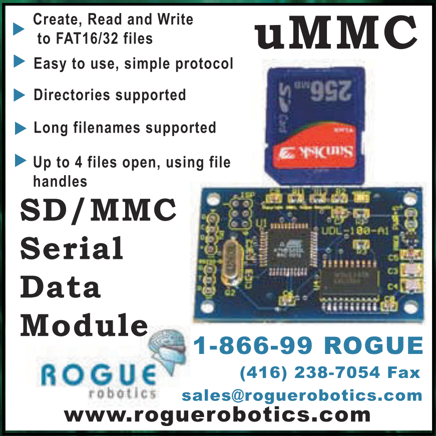


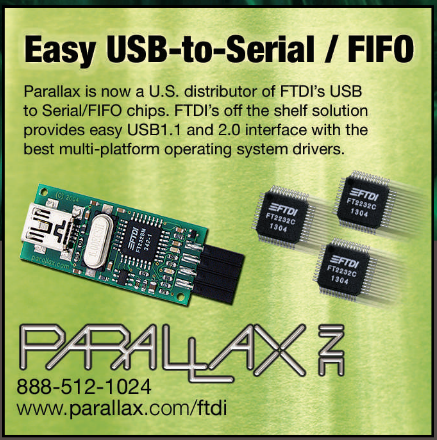
The µCFG allows the digitization and capture of a single color image (field) from a live video signal. Four input video channels (two S-video) and one live output channel are provided. Four external hardware triggers can also trigger a frame capture. Various image download decimation and compression settings are possible. A full evaluation kit is available with PC-based viewer software and source code. Pricing for the complete evaluation kit is $274.00. Individual µCFG modules are $149.00 in single quantity ($99.00/qty. 100).

For more information, contact:

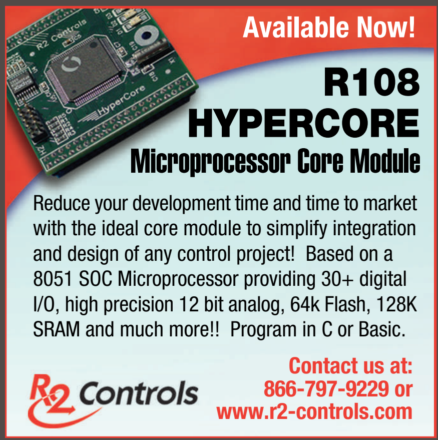
DIGITAL CREATION LABS, INC.
25 Leopard Gate
Brampton, Ontario
Canada L6R 2J5
Tel: **905-793-3603**
Fax: **800-828-3299**
Email: **sales@digitalcreationlabs.com**
Web: **www.digitalcreationlabs.com**

Circle #99 on the Reader Service Card.





Electronics Showcase



Video ... On the Go

Normally, press releases have a lot of "fluff" in them, but, when you read the specs — and the underlying idea behind — ARCHOS, Inc.'s new AV400 PVR (personal video recorder), you'll probably agree with their statement that it is the, “ultimate handheld digital video recorder.” Around the size of a 3” x 5” note card and under 1” thick, the AV400 contains a 20 GB hard drive and mounts in a convenient stand called the TV Cradle. When in the cradle, the AV400 becomes a programmable digital VCR of sorts — accessing a list of TV shows from your Yahoo! TV Guide, tuning to and encoding them in MPEG-4 format. Of course, it also records local TV shows on demand.

Now, here's where the AV400 starts to get neat — it has a 3.5” TFT LCD display so you can watch those

recordings on the go. Also, it has a Compact Flash reader to offload pictures from your digital camera, supporting all the flavors of solidstate memory storage: SD, MMC, SmartMedia, Memory Stick, etc. (Of course, it lets you view those digital images “slide show” style on the LCD.) With its USB 2.0 port, it appears as an additional drive to your computer, allowing you to move data files around, too.

The AV400 comes in a hopped-up version as well, with both a larger hard drive and LCD display. Check the Internet for the latest price, but the fat version should be under $800.00. For more information, visit **www.archos.com**

It's Quite a Stretch

When starting a new computer design, the longest engineering meetings usually beat out the trade-offs between the many competing CPUs that will work in the application. Normally, design engineers are stuck with the functionality of each model offered by the manufacturer — the number of UARTs, ADCs, high-resolution timers, etc. Stretch, Inc., seeks to erase many of those agonizing decisions while simultaneously reducing product design time through its introduction of the S5000 software-configurable processor series.

Using C/C++ and the supplied design tools, engineers can perform a series of powerful optimizations to the Stretch S5000 core. First, external logic can be configured dynamically. This is like receiving all the benefits of a RISC processor core bundled with the programmable logic of an FPGA or ASIC. Second, a scheme named "Instruction Set Extension Fabric" allows custom instructions to be created from high level language

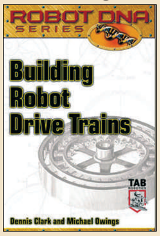
(continued on page 95)

Selected Titles for the Electronics Hobbyist and Technician—

The *Nuts & Volts* Hobbyist Bookstore

Robotics

Building Robot Drive Trains
by Dennis Clark / Michael Owings

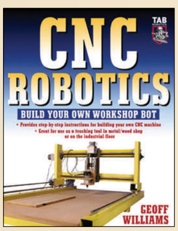


This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

- The Basics of Robot Locomotion
- Motor Types: An Overview
- Using DC Motors
- Using R/C Servo Motors
- Using Stepper Motors
- Motor Mounting
- Motor Control
- Electronics Interfacing
- Wheels and Treads
- Locomotion for Multipods
- Glossary of Terms, Tables, and Formulas

CNC Robotics
by Geoff Williams



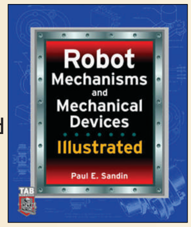
Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

The Robot Builder's Bonanza
by Gordon McComb

A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, LEGO Mindstorms Kits, and other commercial kits. **$24.95**

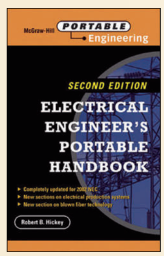
WE ACCEPT VISA, MC, AMEX, and DISCOVER
Prices do not include shipping and may be subject to change.
Ask about our 10% subscriber discount on selected titles.

Robot Mechanisms and Mechanical Devices Illustrated
by Paul Sandin



Both hobbyists and professionals will treasure this unique and distinctive sourcebook — the most thorough and thoroughly explained compendium of robot mechanisms and devices ever assembled. Written and illustrated specifically for people fascinated with mobile robots, *Robot Mechanisms and Mechanical Devices Illustrated* offers a one-stop source for everything needed for the mechanical design of state-of-the-art mobile bots. Written by a leading designer of robots used at the horizon of mobile robotics, this resource offers a collection of both new and classic robotic mechanisms and devices unmatched in scope — from such high-level sources as the mechanical engineers' mainstay, *Mechanisms and Mechanical Devices Illustrated*. Paul Sandin's superlative reference also brings you new robotic mechanisms and devices that have never before been collected! **$39.95**

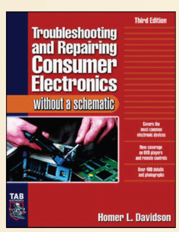
Electrical Engineer's Portable Handbook
by Robert Hickey



This quick look-up, working tool — packed with tables, charts, and checklists — takes the guess work out of almost any electrical design task or calculation. Indispensable for electrical engineers, designers, and technicians, the *Handbook* provides immediate fingertip access to the fundamental information busy professionals need for everyday use in the field. **$59.95**

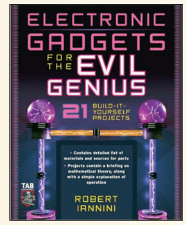
Electronics

Troubleshooting & Repairing Consumer Electronics Without a Schematic
by Homer Davidson



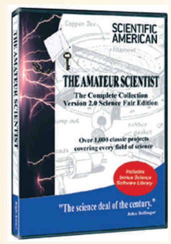
In this book, Homer Davidson gives you hands-on, illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Electronic Gadgets for the Evil Genius
by Robert Iannini



The do-it-yourself hobbyist market — particularly in the area of electronics — is hotter than ever. This books gives the "evil genius" loads of projects to delve into — from an ultrasonic microphone to a body heat detector, all the way to a *Star Wars* Light Saber. This book makes creating these devices fun, inexpensive, and easy. **$24.95**

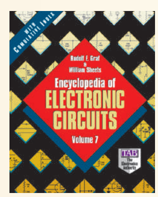
The Amateur Scientist 2.0 Science Fair Edition
from "The Amateur Scientist" column



This CD contains the complete collection — 73 years — of articles from *Scientific American Magazine*'s legendary column "The Amateur Scientist," plus a second Science Software Library CD with dozens of shareware and freeware programs to feed the passion of any science nut. With over 1,100 projects to challenge science enthusiasts of all ages and skill levels — rated by cost, potential hazard, and difficulty — this is the ultimate resource for anyone interested in home-based science. If that's not enough, it also contains over 1,000 bonus pages of additional how-to science techniques that never appeared in *Scientific American*. Great for science fair students, hobbyists of all ages, and home-schoolers! In fact, *The Amateur Scientist 2.0* contains a special primer for science fair students. Fully text-searchable and packaged in an attractive double-CD case, this remarkable browser-based product runs seamlessly on every platform — Windows, Macintosh, Linux, and Unix.

$24.99 — Subscriber
$29.99 — Non-subscriber

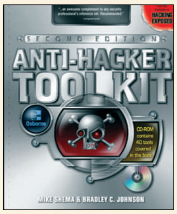
Encyclopedia of Electronic Circuits, Volume Seven
by Rudy Graf



Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits*, Volume Seven, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants, such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

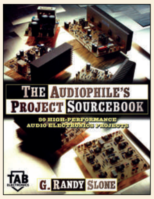
Call 1-800-783-4624 today! Or order online at www.nutsvolts.com

Anti-Hacker Tool Kit, Second Edition
by Mike Shema / Brad Johnson



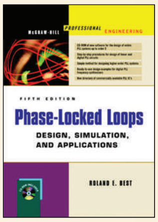
Get in-depth details on the most effective security tools and learn how to use them with this hands-on resource. A must have companion to the bestselling security book *Hacking Exposed*, this tool kit includes tips and configuration advice for getting the best results from the top hacking tools created and in use today. **$59.99**

The Audiophile's Project Sourcebook: 80 High-Performance Audio Electronics Projects
by G. Randy Slone



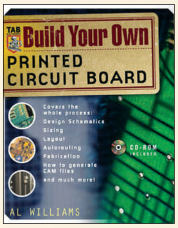
The Audiophile's Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

Phase-Locked Loops
by Roland Best



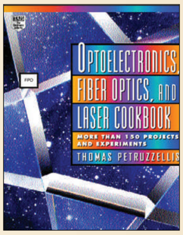
The fifth edition of this classic circuit reference comes complete with extremely valuable PLL design software written by Dr. Best. The software alone is worth many times the price of the book. The new edition also includes new chapters on frequency synthesis, CAD for PLLs, mixed-signal PLLs, and a completely new collection of sample communications applications. **$79.95**

Build Your Own Printed Circuit Board
by Al Williams



With *Build Your Own Printed Circuit Board*, you can eliminate or reduce your company's reliance on outsourcing to board houses and cut costs significantly. Perfect for advanced electronics hobbyists as well, this easy-to-follow guide is by far the most up-to-date source on making PCBs. Complete in itself, the handbook even gives you PCB CAD software — on CD — ready to run on either Windows or Linux. (Some PCB software costs from $10,000.00 to $15,000.00!) **$27.95**

Optoelectronics, Fiber Optics, and Laser Cookbook
by Thomas Petruzzellis



This is a practical guide to one of the hottest fields in electronics and optical circuits. A collection of hands-on experiments and projects for the student, technician, and hobbyist, it explains optoelectronics in nontechnical terms. Projects show how optical circuits work and how to use them in practical and efficient ways. You'll save time, money, and energy with dozens of do-it-yourself projects — from laser alarm systems to high-speed fiberoptic data links. Circuit diagrams, schematics, and complete parts lists accompany each project and an appendix lists suppliers for needed parts. **$29.95**

Electronics Demystified
by Stan Gibilisco

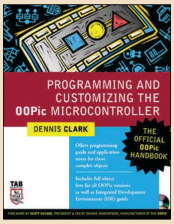
Best selling *Demystified* author and electronics expert Stan Gibilisco has penned the perfect introductory book for consumers, hobbyists, and students alike. Coverage includes essential topics, such as current and power supplies, wireless, digital principles, measurement and monitoring, transducers and sensors, location and navigation, and more. **$19.95**

Microcontrollers

Introduction to Microprocessors and Microcontrollers
by John Crisp

Assuming only a general science education, this book introduces the workings of the microprocessor, its applications, and programming in assembler and high level languages, such as C and Java. Practical work and knowledge-check questions contribute to building a thorough understanding with a practical focus. This book concludes with a step-by-step walk through a project based on the PIC microcontroller. The concise but clearly written text makes this an ideal book for electronics and IT students and a wide range of technicians and engineers, including IT systems support staff and maintenance/service engineers. **$34.99**

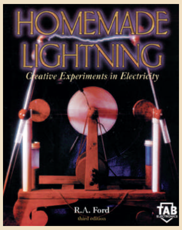
Programming and Customizing the OOPic Microcontroller
by Dennis Clark



If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — *Programming and Customizing the OOPic Microcontroller*. This is the official OOPic handbook, fully endorsed by Savage Innovations — the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

High Voltage

Homemade Lightning: Creative Experiments in Electricity
by R. A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and how experiments in high potential physics work! **$24.95**

Home Entertainment

How to Do Everything with Your TiVo
by Todd Carter

Turn on your TV! This helpful resource helps you select the best TiVo service based on your needs, then shows you how to set up your TiVo, watch live television while your it, record programs, hook TiVo up to your home network, remotely schedule programs to be recorded over the Internet, use multiple TiVos, and much more! **$24.99**

If you don't see what you need here, check out our online store at **www.nutsvolts.com** for a complete listing of the titles available.

New Life for LORAN

Part 1

by Clifford Appel

The US Coast Guard recently retired the most powerful vacuum tube transmitter left in its LORAN arsenal. LORAN still continues to provide navigation service using state-of-the-art technology.

It's not very often that a guy gets to witness "the changing of the guard" during his lifetime, but I've been fortunate enough to do just that. As the years have gone by, we've all seen technology change in unimaginable ways that stun us with "gee whiz" events. December 8, 2003 marked the beginning of the end in an era of vacuum tube LORAN "C" (LOng RAnge Navigation) transmitters.

The last of the US Coast Guard's highest powered vacuum tube transmitters (AN/FPN-45) — 1.6 megawatts pulsed power output — was shut down on that date. In its place, a solidstate transmitter (Accufix Model 7500) at 1.3 megawatts was placed on air to continue the LORAN legacy at LORAN C Station George, WA.

LORAN's history dates back more than six decades, with LORAN "A" sprinkled near coastlines around the world. It was the major wide area coverage navigational system before LORAN "C" was implemented, eventually replacing the "A" stations.

LORAN A operated on 1750, 1850, 1900, and 1950 kHz. Amateur radio operators using 160 meters were restricted in frequency use and DC power input — daytime and nighttime — depending upon geographic location in the US and Canada. The restrictions were imposed because of anticipated interference to LORAN A signals. Gradually, LORAN C stations took over the navigation duties and forced the LORAN A stations into history. The last series of A stations were taken off the air from July 1979 to July 1980 in the US. Amateurs no longer suffer 160 meter restrictions.

How It Works

LORAN is an electronic type of navigation for which users require a receiver. These days, most people are familiar with the ubiquitous GPS (Global Positioning System) units. The user turns on the power switch of the GPS and, in a matter of minutes, the GPS receiver automatically acquires the requisite number of satellites, makes a series of calculations, and displays geographic position in latitude and longitude. Owners of GPS units are aware that they can do a lot more than that basic function, however.

Unlike GPS — which uses a "constellation" of about 24 LEO (Low Earth Orbit) satellites — LORAN uses a "chain" of land-based transmitters. GPS uses frequencies of 1575.42 MHz and 1227.6 MHz, far removed from the 100 kHz carrier frequency of LORAN C. Modern LORAN receivers work the same way as GPS units, in that the user turns on the power switch and the receiver acquires signals, makes calculations, and

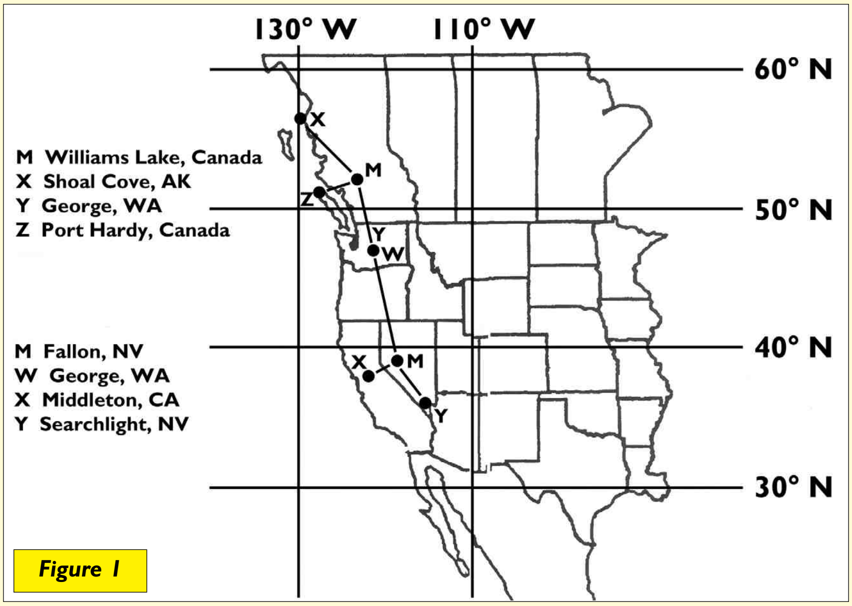


Figure 1

displays geographic positions.

Figure 1 shows two such chains on the West Coast of North America. A chain typically consists of three to five stations. One is designated as the "master" station (letter M) and the others are designated as "secondaries" (V, W, X, Y, and Z). The upper chain of stations shown in Figure 1 is known as the Canadian West Coast Chain and the lower group of stations is known as the US West Coast Chain. It is interesting to note that the station at George, WA participates in both chains (i.e., "Y" secondary in the Canadian chain and "W" secondary in the US chain). That operational mode of gymnastics is called "dual rate" and is performed by several LORAN stations throughout the US and Canada.

So, how do all these stations in a chain play together? Let's look at the US West Coast chain in Figure 1. The master station M at Fallon, NV transmits a series of pulses. The first eight are spaced one millisecond (1 ms or 1,000 microseconds) apart with a ninth pulse spaced 2 ms after the eighth (see Figure 2). A given coding "Time Delay" (TDW) — later secondary station W at George, WA — transmits a series of eight, 1 ms spaced pulses. Another coding Time Delay later (TDX) — secondary station X at Middletown, CA — transmits a series of eight, 1 ms spaced pulses. Lastly, at yet another Time Delay (TDY), secondary station Y at Searchlight, NV burps another eight pulses. The master station always transmits nine pulses for easy identification of its role as master.

The entire process repeats over again in what is called the Group Repetition Interval (GRI). To confuse novices to LORAN terminology, the GRI is given in tens of microseconds. Thus, a GRI of 99,400 microseconds is known as "LORAN rate 9,940." It is the GRI that the LORAN receiver uses to identify the chain to which it's locked on. The TDs between secondary stations vary from one chain — or GRI — to another, so that there's no confusion if the receiver picks up secondaries from another chain. Reference 1 provides information regarding all LORAN chains, station geographic coordinates, GRIs, and TDs. Do you feel like you've just been hit by a can of alphabet soup?

Figure 2 showed all those LORAN pulses as just straight lines, but what do those pulses really look like? Figure 3 shows a LORAN pulse in detail. Remember, the frequency is 100 kHz, so the time between cycles is 10 microseconds. The shape of the "envelope" of the pulse is no accident. It is built up in such a way that the peak amplitude is reached 65 microseconds after beginning the pulse.

The third cycle crossing "zero" on the horizontal axis (time axis) is what the LORAN receiver uses to determine Time Delays (TD) between the master and secondaries. The pulse is intentionally damped after peak so that trailing sky waves will not contaminate the beginning of the next pulse. LORAN's virtue is its ground wave, which is more predictable and repeatable than a sky wave. Because of the shape of the pulse, the bandwidth of a LORAN signal is kept to 20 kHz in the spectrum from 90 kHz to 110 kHz.

What do all these received pulses get you? They get time delays between reception of signals from stations in a LORAN chain. In the "old days," these time delays were actually displayed on a readout. The user then took those numbers and entered them into a chart with LORAN lines on it.

Do you remember plane geometry from high school? The chart contained hyperbolas, each of which was a locus of the same time delays between stations. Got that — "hyperbola" and "locus?" One time delay got you on one hyperbola on the chart. The navigator calls this a "line of position" or LOP. Another time delay got you on a second hyperbola on the chart or LOP. The intersection of the two hyperbolas, LOPs, therefore, was the receiver's (your) location and is known as a "fix" in navigational lexicon.

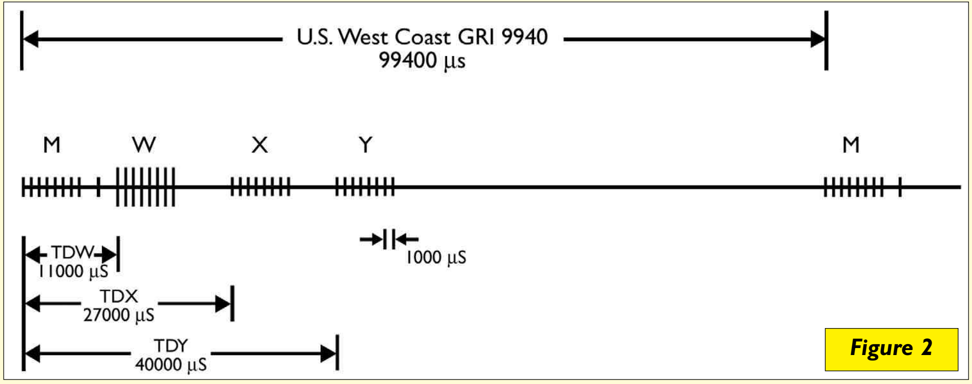


Figure 2

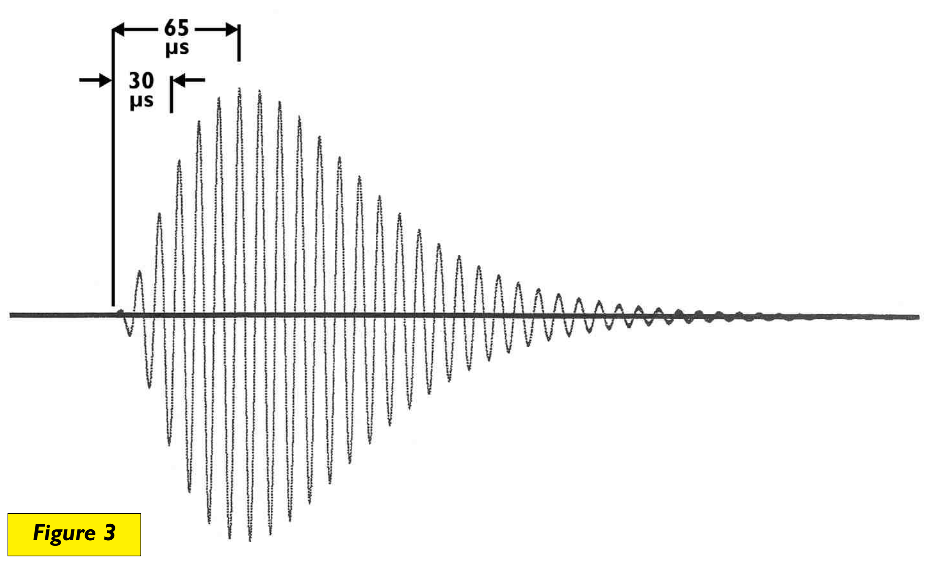


Figure 3

Figure 4. AN/FPN-54 Timing Rack where the LORAN pulses are generated for amplification in the AN/FPN-45 vacuum tube transmitter. Photo courtesy of ETC K. Anderson.

Figure 5. The first IPA, second IPA, and driver/PA tubes are shown from right to left. Note the 12" ruler. The second IPA — in the middle — weighs in at 23 pounds. The driver/PA on the left weighs 21.5 pounds.

Figure 6. One of the two AN/FPN-45 transmitters on air, cranking out 1.6 megawatts.

The receiver needs to acquire three LORAN stations in a chain to provide a fix. Modern, powerful microprocessors and algorithms perform complicated calculations that result in latitude and longitude (Lat/Lon) being displayed instead of time delays, obviating the requirement for a LORAN-specific chart. As with the GPS receiver, most LORAN receivers will do more than simply display Lat/Lon.

The above is a rough idea of the LORAN technique. In reality, it's a bit more complicated; the pulses in an eight-pulse group are phase coded, as well. The TDs are not pure integral numbers, as noted in Reference 1. Some heavy duty signal processing and intense mathematics are going on in the receiver. LORAN's useability is specified down to an SNR of 1:3. You read that correctly.

In other words, if the noise is three times greater than the LORAN signal, you can still acquire a LORAN signal and use it for navigational purposes. In order to perform this magic, the LORAN receiver uses a process known as coherent detection (Reference 2).

The Vacuum Tube Transmitter

Once upon a time, the US Coast Guard had many AN/FPN-45 LORAN transmitters in operation, most of which were scattered on islands in the Pacific Ocean. Those stations were shut down a decade ago, leaving the one at George, WA as the "Lone Ranger" of the high powered vacuum tube transmitters. Presently, the USCG has 10 other vacuum tube rigs (AN/FPN-44), but they only radiate 400 kilowatts of pulsed power. All of these units will be replaced with solidstate units.

Where's the genesis of the operation? The LORAN pulse is developed in the Timing Rack — AN/FPN-54 — which is a solidstate discrete component and integrated circuit technology. Figure 4 shows the equipment. Not shown is a second set of rack panels containing three cesium beam oscillators for precise timing control. More on the cesiums will be detailed later. Also not shown is a third set of rack panels containing monitoring and alarm equipment, known as RAIL — Remote Automated Integrated LORAN. So, there's a lot of peripheral equipment involved in just getting that perfectly formed pulse of Figure 3 fed to the transmitter.

The LORAN pulse is sent to the next room to be pumped up from wimp to Schwarzenegger status in the AN/FPN-45 transmitter. Figure 7 is a block diagram of the tube complement that amplifies just the upper half of the pulse. An identical tube complement amplifies just the lower half of the pulse. I think a lot of older hams know what a 6CL6 and a 6146W look like, but take a look at Figure 5 to see the physical size of the 4PR1000A first IPA

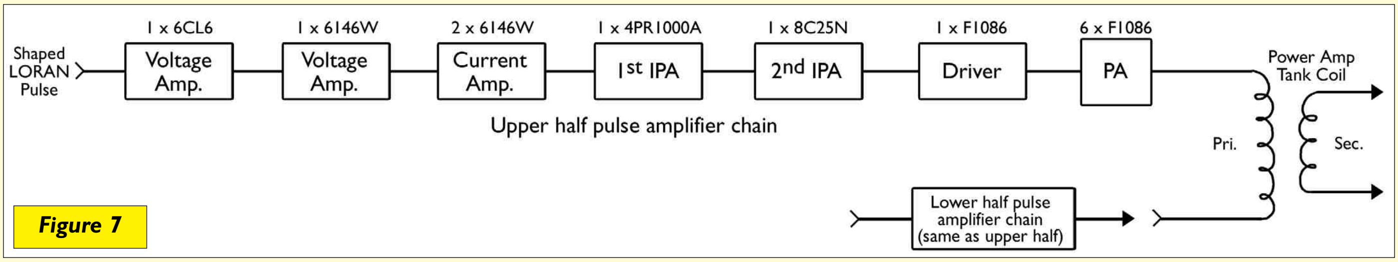


Figure 7

(Intermediate Power Amplifier), 8C25N second IPA, and the F1086 driver and power amps (PA) compared to a standard 12 inch ruler.

The first and second IPAs are air cooled, but the driver and power amplifiers are both air and water cooled. The 8C25N has radial cooling fins inside that big copper anode; the tube weighs in at a hefty 23 pounds. The F1086 has its copper anode cooled by deionized water and air; this tube is a lightweight at 21.5 pounds.

With tubes this large, you can imagine that the voltages involved are commensurate. The PA plate voltage is 21.5 kilovolts with a negative 1,100 VDC grid bias voltage. The PAs are triodes operating in push-pull, class B, with all six pairs operating in parallel. Both IPAs and the driver use a plate voltage of 10,750 volts. Even the bias on the driver tube is wicked at a negative 1,800 volts.

If the plate voltages seem awesome, let me throw some numbers at you regarding the filaments. The 8C25N second IPA uses a filament voltage of 7.1 VAC at 110 amps per tube. The F1086 driver and PA filaments use 12.6 VAC at between 270 to 290 amps per tube. I made some cursory measurements during testing when the vacuum tube transmitter was removed from on-air service and discovered that just lighting the filaments for each transmitter gobbled up about 100 kilowatts.

Taking a look at Figure 6 gives you an idea of the size of the transmitter; there's one on each side of the passageway. One is on-air while the other is in standby to act as a "ready backup." Every two weeks, the transmitters are switched to keep the operating hours about the same on each unit. Every day, there is a requirement to run up the standby transmitter into a dummy load to insure it will function properly in the event the on-air unit fails. At that time, the power demand from the local utility for total LORAN station operation is nearly 1,000 kilowatts. Remember that number when we get to the new solidstate transmitter.

Figure 8 shows the two first IPAs and the two second IPAs in their cabinet. Note the warm glow of the filaments. You can be sure the plate and grid voltages were not on. Figure 9 shows two of the PA tubes (with filaments lighted) and the associated "plumbing" between the two. These tubes are air and water cooled. Thus, you can see the copper pipes and red hoses carrying deionized water to and from them.

Figure 10 shows the inside of a transmitter. The gray unit at the bottom left is the transformer providing the 21.5 kV plate voltage. The red hoses on the bottom right are carrying the deionized water to the driver and PA tubes. The big circular object in the middle is the power amplifier tank coil. It is three feet in diameter and four feet long. The wire forming the coil uses insulation the same as the spark plug wires on your automobile.

I mentioned that the transmitter is air cooled. We don't just open doors and let the wind whistle through. At the end of the transmitter is another room called a "plenum." It's a space about 40 feet wide, 28 feet deep, and 11 feet

Figure 8. The two tubes in the middle are the first IPA (push-pull, class B) amplifying the upper and lower halves of the LORAN pulse. The two outboard tubes with the black anodes are the second IPA, also operating class B. Gotta love those filaments! Photo courtesy of ET1 K. McKinley.

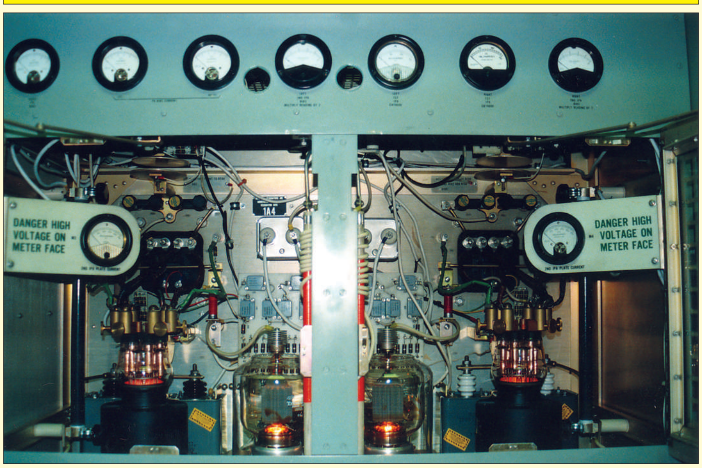
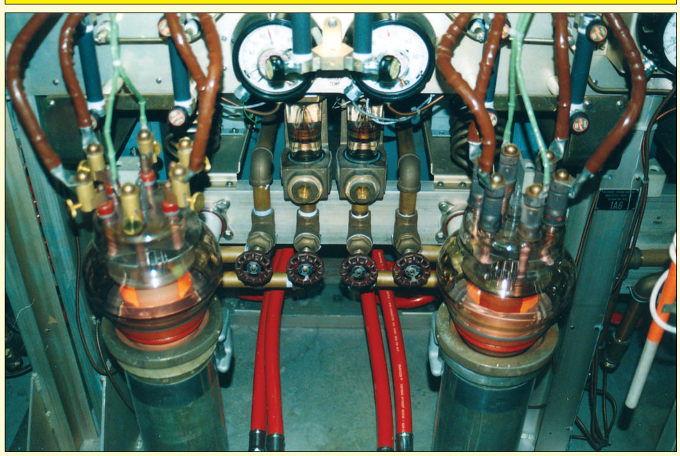


Figure 9. A view of two of the 12 PA tubes with filaments lighted. The red hoses carry deionized water around the tube for cooling. Additionally, all the tubes inside the transmitter are cooled by circulating air at 55° F. Photo courtesy of ET1 K. McKinley.



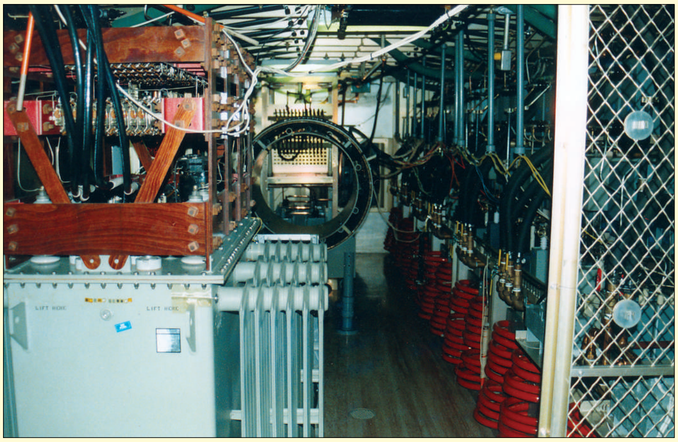


Figure 10. A view inside the transmitter with plate and bias voltages off, of course. Photo courtesy of ET1 K. McKinley.

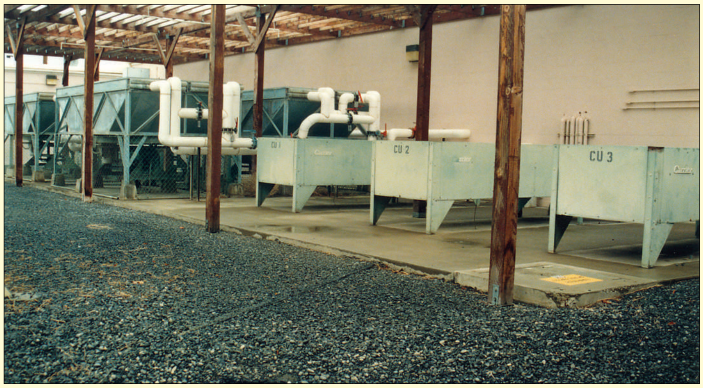


Figure 11. This is what it takes to remove the heat from the transmitters. The A/C units are rated at 30 tons each. There are four heat exchangers (HEX) to cool the deionized water used for the driver/PA tubes. Photo courtesy of ET1 K. McKinley.

high with three "air handlers" — or blowers — that circulate refrigerated air around the plenum. That cold air (kept at 55° F) is sucked into the transmitter cabinet for cooling those big tubes.

The cooled air for the plenum is provided by three, 30 ton air conditioning units, which are shown in Figure 11. The devices with the white pipes on them are the heat exchangers (same concept as an automobile radiator) that cool the deionized water used for cooling the PA tubes. You have to get rid of the heat from that big transmitter somehow and you can see what a major effort it is by noting the physical size of the equipment.

Everything about this transmitter is big: the power consumption, the vacuum tube sizes, the heat generated, the lethal voltages used, the cost of parts, and maintenance time and costs. The monthly electric utility bills were running over $9,000.00 per month. All first IPAs are swapped out every three months. Every six months, the second IPAs are swapped out if they even show a hint that they are deteriorating. Those big drivers and PAs are "nominally" changed out at two-year intervals, depending upon each tube's condition.

The 4PR1000A first IPA costs about $1,300.00 new. The 8C25N second IPA is no longer made, so they are rebuilt to the tune of about $1,600.00 each. The F1086 drivers and PAs are no longer made, either, and it costs about $2,300.00 to rebuild one. Remember, there are 12 PAs and two drivers per transmitter. Okay, you "bean counters," break out your calculators.

Now you know why the US Coast Guard is investing in a new transmitter to replace the aging vacuum tube gear. Next month, I'll introduce you to the details of the solid state transmitter. **NV**

References

Reference 1 — **www.navcen.uscg.gov/loran**
Click on "LORAN-C User Handbook." Although this publication contains information regarding LORAN stations long since shut down, it is a good tutorial for providing insight as to how LORAN works.

Reference 2 — Private correspondence March 5, 2004 with Bill Roland, a retired engineer from Megapulse, Inc.

About the Author

You may contact Clifford J. Appel, K7SPS, at cjappel@juno.com

by Bob Armstrong

The Stereo 6T9

Building a Vacuum Tube Amplifier

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

There's a magic in building audio amplifiers that I've never found in a thousand microprocessor projects and — if that amplifier happens to glow in the dark with the soft light of vacuum tube filaments — so much the better. This project is a simple introduction to vacuum tube amplifiers. No one will accuse it of being HiFi, but it's easy to assemble using a printed circuit board, uses only a handful of readily available components, and — best of all — the vacuum tubes and transformers used are cheap enough to not break the bank, even if you have to buy them brand new.

Output power from this stereo amplifier is approximately 4 W per channel. If you mount it in a nice enclosure and give it a pair of efficient speakers to work with, it makes a pleasant amplifier for a PC sound card or a portable CD or MP3 player. Yes, it is anachronistic to use a vacuum tube amplifier with a PC and your coworkers will probably think you're slightly off balance, but that's part of the appeal.

Warnings

Unlike battery-operated transistor or IC circuits, vacuum tubes can be dangerous. Not only is this project powered from the AC power line, but it contains voltages as high as 500 volts. ***These voltages can be lethal!***

Figure 1. The Stereo 6T9 with small MP3 player.

The safest way to work on this circuit is to always disconnect the power before making any changes or connecting any test probes. Make sure that you are well clear of the circuit and any test leads before applying power. If you must work on it while it is on, always think about where both of your hands are! Follow the old radio man's rule of keeping one hand in your pocket at all times.

Remember that high voltage capacitors such as C1 and C2 can store lethal voltages for hours after the power is removed. This circuit has a bleeder resistor — R3 — which normally drains the charge from these capacitors within a few seconds, but never assume that it's working. Resistors can fail, so always check the voltage on these capacitors or short them out before working on the circuit.

Finally, power tubes — such as the 6T9 — get very hot in normal usage. You can easily get burned by touching the 6T9 envelope!

Circuit Description

Figure 2 shows the schematic for one channel of the Stereo 6T9 amplifier; the other channel is identical. With the exception of V1/V2 and T1/T2, all parts numbered 1xx (e.g., R101, C104, etc.) are part of channel one and parts numbered 2xx (e.g. R201, C204) are the corresponding parts for channel two.

The circuit used is a classic two stage amplifier. The triode section of V1 serves as a voltage amplifier with a gain of approximately 10-15x and the pentode section is a power amplifier with an audio output of around 4 watts. If you do not know anything about how vacuum tubes work, you might want to read the sidebar before reading further.

Capacitors C101/C201 AC couple the signal to the grid of the triode section and block any possible DC offset from the signal source that might affect our bias. Resistors R101/R201 are "grid leak" resistors — they ensure that the grid has a DC path to ground. Of all the electrons that pass from the cathode to the

plate of the tube, a few will strike the grid by pure chance. Unless these electrons have some place to go, they will accumulate on the grid and cause it to build up a steadily increasing negative voltage. Eventually, enough electrons build up on the grid to completely block any current flow to the plate and the tube stops working. The grid leak resistors give these extra electrons a path to ground.

Resistors R102/R202 develop approximately 1.4 V drop because of the plate current of around 0.6 mA that always flows through the triode. By raising the voltage of the cathode to +1.4 V, we effectively give a negative bias of -1.4 V to the grid of the tube — a technique known in the vacuum tube world as self bias. It is very similar to a transistor amplifier, but — unlike transistors — tubes can be operated with either a positive or negative voltage on the grid and it is possible to operate a tube stage without any bias at all. In this case, the -1.4 V bias on the tube is to put us into a more linear portion of the tube's operating curve and reduce the distortion.

Vacuum tubes are essentially voltage controlled current sources and the changes in the grid voltage caused by the input signal cause a corresponding change in the plate current, which appears as a larger change in the voltage across the 120K plate resistors, R103/R203. This amplified signal voltage is coupled to the next stage by DC blocking capacitors C102/C202.

The operation of the pentode stage is very similar. In this case, R104/R204 are the grid leak resistors and approximately 8 V of cathode bias is developed by R105/R205. This much larger bias voltage is developed by the much larger plate current of the pentode — approximately 30 mA — and is necessary because of the larger signal level applied to the pentode's grid. In this stage, the cathode resistor is bypassed by 100 µF capacitors — C104/C204 — which place the cathode at AC ground and increase the gain of this stage. By the way, it would have been desirable to use similar bypass capacitors on the triode stage, but they would have defeated the negative feedback applied there.

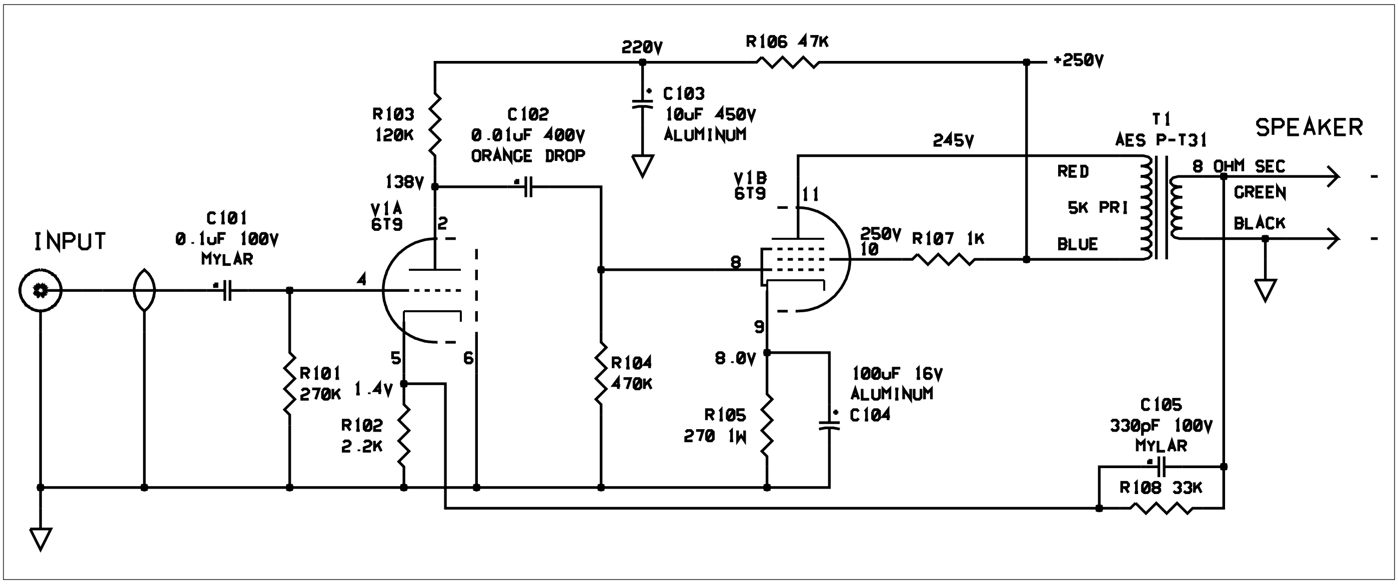
In the case of the pentode, there is no plate load resistor — the output transformers T1/T2 take its place and match the relatively high — approximately 5K — plate load impedance of the pentode to an 8 Ω loudspeaker. Resistors R107/R207 apply the screen voltage to the pentode section and are there to prevent parasitic oscillations. Their value is too small to have any appreciable voltage drop under normal conditions.

Resistors R108/R208 couple a small portion of the output signal back to the cathode of the triode section. A positive voltage at the output will raise the cathode voltage which has the result of canceling the input signal. This is called negative feedback and, while it might seem like a strange thing to do, it is actually quite beneficial. The effect is that any signal component that appears in the output of the amplifier — but which is not in the input (e.g., distortion, noise, etc.) — cancels itself out by creating a corresponding negative correction at the input of the amplifier.

Negative feedback reduces the distortion in the output of the amplifier; it flattens the frequency response and improves the damping factor. It's worthwhile to note that many very high end amplifiers forgo negative feedback because it can lead to other undesirable secondary effects; however, in a simple amplifier like this one, negative feedback offers a big improvement. Capacitors C105/C205 increase the amount of negative feedback at very high frequencies and are there to prevent the amplifier from oscillating at ultrasonic frequencies.

Figure 3 shows the schematic of the Stereo 6T9 power supply. The power supply is very simple, using a full wave center tapped rectifier followed by two stages of RC

Figure 2. One channel of the Stereo 6T9 amplifier.



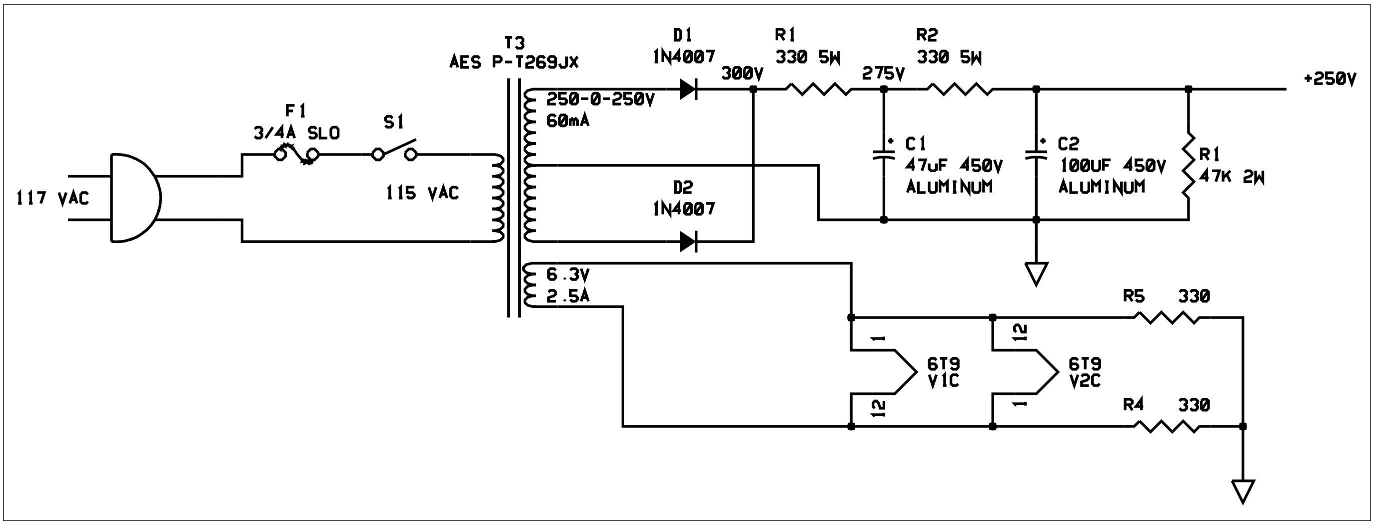


Figure 3. Stereo 6T9 power supply.

filtering. In older days, an LC filter would have been used instead, but inductors are large, heavy, and expensive. Today, there are much better electrolytic capacitors available than there were back then and it's possible to get by using a resistor instead of the filter choke. Resistors R106/R206 and capacitors C103/C203 provide extra filtering for the triode section's plate supply, which further minimizes the amount of hum present at this sensitive stage.

Construction

You can easily build this amplifier using entirely point-to-point wiring; however, a printed circuit board makes construction a breeze and eliminates a lot of the opportunities for error. A double-sided, silk screened, and solder masked PC board is available from the source specified in the Parts List, and the images are available for download from the *Nuts & Volts* website at **www.nutsvolts.com**

If you use the PC board, remember that it mounts upside-down in the enclosure so that the tube sockets need to be mounted on the solder side (that is, the side without the silk screen) of the board. All other components mount on the component (silk screen) side. Capacitor C2 is large and heavy enough that the leads alone are not sufficient to secure it to the PC board; so, after soldering, wrap a wire tie around the middle of C2 and through the two holes provided in the PC board to hold it in place.

The power resistors — R1, R2, and R3 — get quite hot in normal operation and should not be installed touching the PC board. Leave about a 1/8" to 1/4" air gap underneath these resistors when soldering them to allow air flow around them and to prevent heat damage to the PC board.

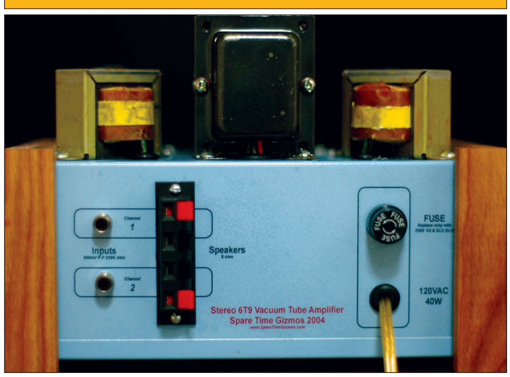
You may have trouble finding 400 V capacitors for C102/C202, but these parts are subjected to the maximum power supply voltage during the vacuum tube warm up period and any lower voltage rating is not safe. Also, avoid using ceramic capacitors for C105/C205. Ceramic capacitors have poor sound quality and should never be used in audio equipment — always use film type capacitors instead.

Shielded cable — preferably RG-174 miniature coax — *must* be used for the wiring between the PC board, the volume control (if you use one), and the input jacks. The shielded cable should be run right up to the PC board so that no more than 1/4" or so of unshielded center conductor is exposed at the connection.

If you elect to build the amplifier without a PC board, use care to keep the lead lengths around the triode's grid — pin 4 — as short as possible. The 6T9 packs a fair amount of gain into a small space, not to mention that there are almost 200 volts of audio AC on the pentode's plate

Figure 4. Front view.

Figure 5. Rear view.



and it only takes the smallest amount of coupling to the triode's grid to induce feedback and oscillation. The PC board layout is carefully arranged to provide maximum isolation for pin 4 and you shouldn't have any problems with it, so long as you remember to use shielded cable.

Solderless screw terminal strips are used for all connections to the PC board, except the shielded input leads. These are optional, of course — you can just solder the wires directly to the PC board — but, if you ever need to remove the PC board for repair, you'll be glad that they are there!

The PC board should be mounted in the chassis upside-down using 7/16" standoffs and #4-40 hardware. The solder side and the tube sockets face up and the sockets protrude through 1-1/8" holes in the chassis. If the standoffs are correct, then the top of the tube sockets should be just about flush with the chassis. Be sure that none of the solder joints on the bottom of the PC board short to the chassis!

Figure 8 shows the interior of the assembled Stereo 6T9. The long transformer leads may look messy, but the usual wisdom is to never cut them off. Transformers are very expensive and you don't know when you might want to re-use them in a different project! Wire ties can be used to keep the high voltage leads neatly bundled and away from the sensitive inputs.

Grounding

If you examine the PC board, you'll see large areas of copper that are the circuit ground. Notice that these areas do not form a complete loop around the outside of the PC board because to do so would form a ground loop. Also notice that the eight mounting holes are isolated from the ground plane and — when you install your PC board in a metal case — you should make sure that the mounting screws do not inadvertently touch the PC board ground plane.

The entire circuit should be grounded to the metal case at exactly one point — the input jacks — through the shield of the input coaxial cable. Grounding the circuit to the metal case at more than one point will always result in ground loop problems.

If you build your amplifier without a PC board, then you should try to duplicate this grounding arrangement. The usual way to do this is to run a bare piece of heavy

Parts List

Resistors

All resistors are 1/4 W 5% carbon composition unless otherwise specified.

R1, R2 - 330 Ω, 5 W wire wound
R3 - 47K, 2 W
R4, R5 - 330 Ω
R101, R201 - 270K
R102, R202 - 2.2K
R103, R203 -120K
R104, R204 - 470K
R105, R205 - 270 Ω, 1 W
R106, R206 - 47K
R107, R207 - 1K
R108, R208 - 33K

Capacitors

C1 - 47 µF 450 V axial lead aluminum electrolytic capacitor (AES1C-ET47-450)
C2 - 100 µF 450 V axial lead aluminum electrolytic capacitor (AES C-ET100-450)
C101, C201 - 0.1 µF 50 V film capacitor
C102, C202 - 0.01 µF 400 V "Orange Drop" capacitor (AES C-PD022-400)
C103, C203 - 10 µF 450 V radial lead aluminum electrolytic capacitor
C104, C204 - 100 µF 16 V radial lead aluminum electrolytic capacitor
C105, C205 - 330 pF 100 V film capacitor

Actives

V1, V2 - 6T9 vacuum tube (AES T-6T9)
D1, D2 - 1N4007 silicon diode

Transformers

T1, T2 - Output transformer, 5K primary to 8 Ω secondary (AES P-T31)
T3 - Power transformer, 250-0-250V 60 mA, 6.3 V 2.5 A (AES P-T269JX)

Miscellaneous

6T9 (12FM) PCB mount tube sockets (AES P-ST12-114)
Two-pin 0.2" terminal block (Digi-Key ED1643)
Three-pin 0.2" terminal block (Digi-Key ED1644)
3/4 A 250 V "SLO BLO" fuse
Panel mount fuse holder (RadioShack 270-364)
Power switch (RadioShack 275-692)
Speaker terminals (RadioShack 274-622)
RCA Jacks (RadioShack 274-346)
Printed circuit board
8" x 6" x 3.5" metal chassis (LMB TITE-FIT 783)

You may purchase a double-sided, silk screened, and solder masked PC board for this project, a punched and drilled enclosure, the decorative wooden end panels shown in the photographs, or a complete kit of all parts needed to build this amplifier from Spare Time Gizmos. Visit our online store at **www.SpareTimeGizmos.com/Store.htm** to order one or send an Email to orders@SpareTimeGizmos.com for more information.

If you want to make your own, you may download the complete Gerber and drilling files for the PC board, a full sized drilling guide (just print it out, tape it to the box and drill where you see "X"!) for the chassis, and the artwork for the decals that you see in the photographs from **ww.SpareTimeGizmos.com/Download.htm** as well as the *Nuts & Volts* website, **www.nutsvolts.com**

Visit our website for this project, **http://Stereo6T9.SpareTimeGizmos.com** for the latest news, updates, and corrections.

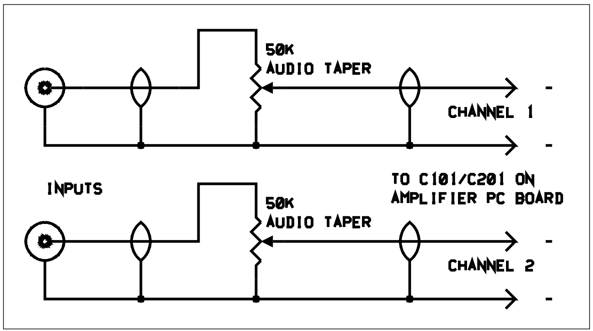


Figure 6. Adding a volume control.

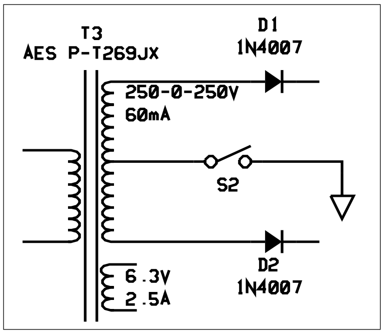


Figure 7. Delayed turn on switch.

gauge copper wire the length of the chassis and support it with insulated standoffs. All ground connections should be made to this wire and then the wire is connected to the chassis at one and only one point — the input jacks.

Ground loops can be a serious problem if a three-wire power cord is used and the amplifier is connected to another device with a three-wire power cord, such as a PC. The simplest solution is to use a two-wire line cord for the amplifier and avoid this problem completely, but this raises safety issues.

The only way to both be safe and avoid ground loops is to completely separate the signal ground from the power ground. Since — if you did everything right — the signal ground is only connected to the case at one point — the input jacks — this is easy enough to do by using insulated washers to isolate the RCA jacks from the metal case. Now you can connect the power ground (that green/yellow wire in the power cord) to a ground lug installed under one of the power transformer's mounting screws.

This will work, but — if you ever operate the amplifier while it's connected to an ungrounded device (such as a

How Tubes Work

In 1883, Thomas Edison — while trying to improve his light bulb — decided to place a metal plate inside the glass envelope along with the filament. No one knows why he did this, but Edison — who was always somewhat of a tinkerer — was probably just guessing. In any case, the plate did nothing to help his light bulb and he gave up on it, but not before he noticed that a current would flow if the plate was connected to the filament.

We know today that the electrons orbiting the atoms of the filament had enough energy at the white hot temperatures to escape from the filament and form an electron "cloud" inside the tube. The electrons, which are negatively charged, would be attracted to a positively charged metal plate and allow a current (which after all, is nothing more than a movement of electrons) to flow between the filament and the plate.

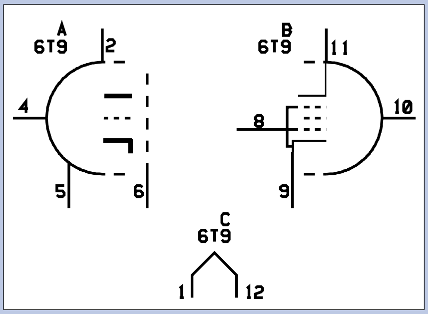
Edison had just invented the first vacuum tube (a diode), but it would take another decade before the physicist J. J. Thomson would discover the existence of the electron and Edison never had any idea how or why his tube worked. It was Sir John Fleming — who had been working in Edison's labs in 1883 — who had the idea of applying the vacuum tube to radio reception; however, as a simple diode, it couldn't do much.

It wasn't until 1906 that Lee DeForest had the idea to place a third element in the tube — a fine coil of wire between the filament and the plate. By applying a negative voltage to this coil of wire, it could repel the electrons and prevent them from ever reaching the plate; conversely, applying a positive voltage to the grid would cause even more electrons to speed toward it, pass between the coils of wire, and hit the plate. Thus, a fairly small change in the voltage on the grid could cause a large change in the plate current and now the vacuum tube could amplify it.

The 6T9 tube used in this project was designed by Sylvania in the 1950s and it actually contains two separate, independent tubes in the same glass envelope; it's a little like an integrated circuit from the vacuum tube era! The first part is a triode — not all that different from the one Deforest invented in 1906. The audio voltage is applied to the grid and the resulting change in the plate current causes a much larger voltage to be developed across the plate resistor. This amplified voltage is then coupled to the grid of the second section of the 6T9.

The second half of the 6T9 is a pentode — a tube with no less than three grids. All triode amplifiers suffer from the problem that the plate current depends to some extent on the plate voltage in addition to the grid voltage and the plate voltage naturally changes as it follows the signal that we're amplifying. This tends to make the tube "oppose itself" and cancels out a part of its gain. While we can't prevent the plate voltage from changing with the signal, we can make the plate current insensitive to the plate voltage by adding what will be a fourth grid — called a screen grid — between the first grid and the plate. If this fourth grid is connected to a large, fixed positive voltage, then it does the work of attracting electrons to the plate and the number of electrons reaching the plate no longer depends on the plate voltage.

Schematic symbol for the 6T9 vacuum tube.



The third and final grid — called the suppressor grid — is placed between the screen grid and the plate. If there were no suppressor grid, the fast moving electrons would tend to strike the plate and bounce off, returning to the positively charged screen grid. This has the effect of reducing the plate current and increasing the screen grid current, which doesn't help us amplify at all. By connecting the suppressor grid to a negative voltage and placing it between the plate and screen, we can prevent those electrons from leaving the plate and increase the power output of the tube.

battery-operated CD or MP3 player) — then you'll have hum because the amplifier case is no longer connected to the signal ground. To fix this problem, you need to connect a small, 0.01 µF capacitor between the signal ground (at the RCA input jacks) and the chassis. Be sure to use a capacitor rated for AC line service.

Checkout

When you've completed the wiring, go back and double check everything again. Look particularly for short circuits around the high voltage components (e.g., D1, D2, C1, C2, R1, R2, and R3) — an accidental solder bridge here will destroy components! Be sure that C1 and C2 are installed in the correct orientation with the negative side connected to the ground plane. *Electrolytic capacitors can explode if connected backward!*

When you're ready to proceed, attach two speakers to the output terminals, but don't make any connections to the inputs yet. Before you plug it in, connect a DC voltmeter set to at least a 1,000 VDC scale to ground and the positive side of C2. Pay careful attention to how you make this connection — remember, the voltmeter leads will have at least 400 V on them when you apply power, so be absolutely certain that there's no way you can accidentally touch one or cause one to contact any metal parts.

Turn on the power and the voltage on C2 should immediately rise to about 375 V. You'll see the tube filaments (there are two in each tube) glow and — after about a 10 second warm up — the voltage on C2 should drop to approximately 250 V. If the initial voltage exceeds 450 V or if it doesn't drop to something below 275 V after 10 or 15 seconds, immediately turn off the power and figure out what you did wrong.

If all is well, turn off the power, connect a signal source (your PC, an MP3 or CD player, or something like that) and turn it back on. After a short warm up period, you should be rewarded with music from the speakers.

If you hear a terrible howling or screeching sound — like feedback — then that's exactly what it is — feedback. If you use the transformers specified in the Parts List and follow the color code shown, then you shouldn't have this problem, but if you use a different transformer it is possible that the polarity of the output is reversed. This turns the negative feedback into positive feedback and that turns the amplifier into an oscillator! The fix is easy — just reverse the leads for either the primary or secondary (but not both) winding on the output transformer.

Adding a Volume Control

No volume control is included because it's assumed that whatever source you use will already have one. If you want to add a volume control to the amplifier, Figure 6

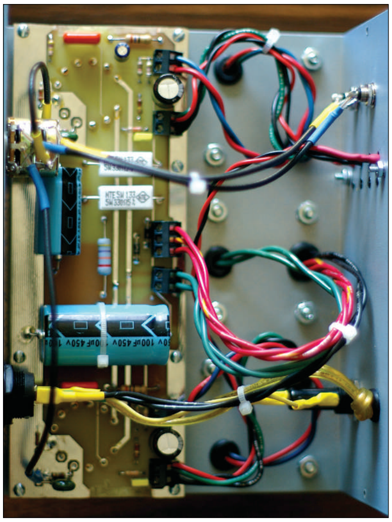


Figure 8. Interior of the Stereo 6T9.

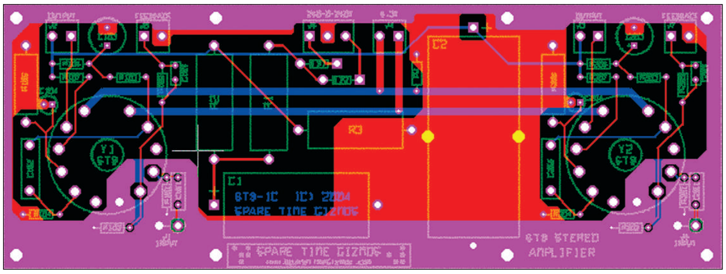


Figure 9. X-ray view of the printed circuit board layout.

shows how you can connect a 50K audio taper stereo pot. Pots like this are becoming hard to find these days, but you can get a suitable one from Antique Electronic Supply.[1]

If you find that you need more gain, you can experiment with increasing the value of the feedback resistors, R108/R208. Increasing these values will decrease the negative feedback and, in turn, increase the overall gain, but at the cost of some sound quality. You can also try looking for more efficient loudspeakers; with the right speakers even a 3-4 W amplifier like this one can play amazingly loud.

Adding a Delayed Turn On Switch

Because this amplifier uses solid state rectifiers in the power supply, the high voltage is applied to the tubes the instant the power is switched on. Applying high voltage to tubes before the filaments have had a chance to warm up is often considered a bad practice and can lead to a phenomenon known as cathode stripping, which shortens the lifetime of the tubes.

Figure 7 shows how you can add an additional switch (S2) to control the high voltage separately. To turn the amplifier on, you turn on S1 (First, make sure that S2 is off!) to warm up the filaments without any high voltage present. After waiting 15 to 20 seconds, you then turn on S2 to apply the high voltage to the tubes. When you're done using the amplifier, you normally switch off both S1 and S2 at the same time.

By the way, many higher end vacuum tube amplifiers — especially those with very expensive vacuum tubes — typically use a relay and an automatic delay circuit to accomplish this switch-on function. **NV**

Resources

1 AES is Antique Electronic Supply, 6221 S. Maple Ave., Tempe, AZ 85283 US, (800) 706-6789 or (480) 820-5411, **www.tubesandmore.com**

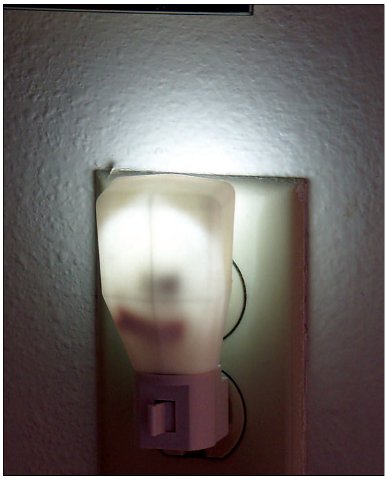
2 Digi-Key Corporation, 701 Brooks Ave. South, Thief River Falls, MN 56701 US, (800) 344-4539 or (218) 681-6674, **www.digikey.com**

3 If you live outside the US, you can order from RadioShack at **www.radioshack.com** Otherwise, there's probably one in your neighborhood.

A White LED Night Light

With a Primer on AC Capacitors

I discovered LEDs back in 1974, and thought they were the coolest thing ever. I was still in high school at the time and I was just starting to play with TTL. While others my age were out partying and chasing girls, I was getting my jollies by watching red LEDs count in binary. That's probably why I didn't have a lot of friends.



Then, along came green LEDs and, finally, blue and I figured that the white LED wasn't far off. It wasn't, but the technology used to manufacture the first mass produced white LED was not what I expected. I figured it would consist of an array of red, green, and blue LEDs. Apparently, this was tried, but the result was more colorful than it should have been.

It was Shuji Nakamura — the inventor of the blue LED — who came up with a rather clever way of achieving white: use a super bright blue LED to excite yellow phosphorous. The combination of the yellow glow and the blue that leaks through produces white light. Why do blue and yellow make white, not green? Because yellow is a combination of red and green — two of the primary colors of light. Add blue (the third primary color) and — alakazam — you get white!

Super bright white LEDs are not bright enough, yet, for practical room lighting, but they can be used to make a nifty and fairly inexpensive night light — though it is questionable whether it will last long enough to pay for itself, but more on that later.

The Design

Since this night light will be powered by 120 volts AC, it is necessary to reduce the source voltage down to the level required to power six series connected LEDs (around 20 volts). This could be done with a resistor, which would dissipate around 2 watts RMS, but that would be wasteful. Also, because the life span of a white LED is markedly reduced as its temperature increases, something will have to be done with all that heat.

A capacitor is essentially an AC resistor that can divide voltage without dissipating any power. (Okay, there is a slight loss of power in the plates, leads, and dielectric, but — if you choose the right capacitor type — this is negligible, especially at a frequency as low as 60 Hz.

How does a capacitor affect a voltage drop without dissipating power? It does this by shifting the phase relationship between the current and the voltage by 90°. The formula for sine wave AC power is:

$$P = IV\cos\varphi$$

where **I** is the peak current, **V** is the peak voltage, and **φ** is the phase difference between the voltage and the current. Since cos 90° is zero, the power is zero! How lovely is that?

This is really just a simple series circuit. C1 acts as an AC resistor in series with the six LEDs. LEDs of this ilk usually drop anywhere from 3.0 to 3.5 volts when powered at 20 mA, so six in series will drop from 18 to 21 volts.

I like to be a bit conservative when powering white LEDs because of their susceptibility to heat. The more current you send through them, the hotter they get. (LEDs get hot? You bet! Try packing a bunch of them into an enclosed space and running them at 20 mA and see how hot they get!)

Most data sheets for white LEDs say you can run them as high as 30 mA, but data sheets that include a projected life span indicate a marked reduction at this current. (Life span is usually defined as the length of time it takes the luminance of an LED to fall to 50% of its original brightness.) According to Lumitex (**www.lumitex.com**), even at 20 mA, white LEDs are estimated to last only

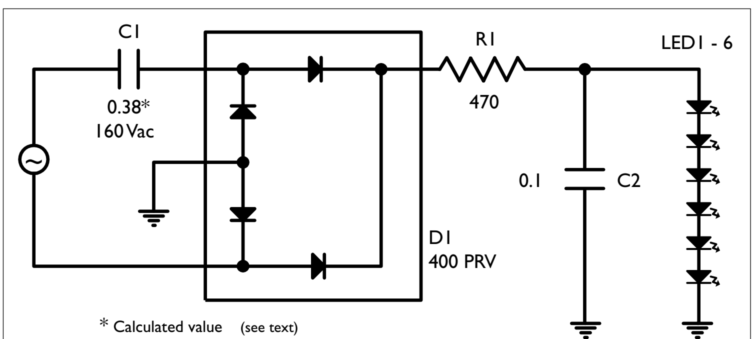


Figure 1

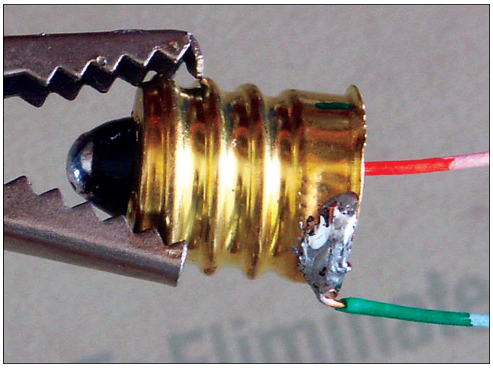


Figure 2. Lamp base with new wires.

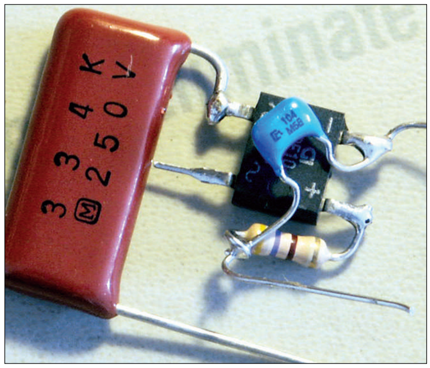


Figure 3. Power supply construction.

$$169 \text{ volts} - 20 \text{ volts} = 149 \text{ volts}$$

Divide that by 20 mA to get the series resistance:

$$149 \text{ volts} / 20 \text{ mA} = 7.5\text{K}$$

In the schematic (Figure 1), there is a 470 Ω resistor (R1) in series with C1. This — along with C2 — forms a filter to help protect the LEDs from voltage spikes (they're kind of sensitive to that, too).

18,000 hours at 25° C. Drop that to 10 mA and the life span goes up to 40,000 hours. I chose to run them at 20 mA peak, which is around 14 mA RMS.

Since a full-wave rectifier doubles the frequency applied to it, the LED current will peak every 8.3 milliseconds (1 / (2 * 60 Hz) = 8.3 ms), which makes them seem nearly as bright as they would be if they were run continuously at 20 mA, yet they are given a chance to cool down a bit between pulses.

To determine the series resistance, multiply the RMS voltage from the wall by the square root of 2 (around 1.41) to get the peak voltage:

$$1.41 * 120 \text{ volts} = 169 \text{ volts}$$

Now, subtract the 20 mA voltage across the LEDs (an average of 3.3 V per device or about 20 volts):

So, that leaves around 7K for the dropping capacitor. Apply a little algebra to the formula for capacitive reactance:

$$X_C = 1/2\ \pi f C$$

where **f** is the frequency and **C** is the capacitance, you can get the value for the dropping capacitor:

$$C = 1/2\ f X_C$$

or

$$C = 1/2\ \pi 60(7\text{K})$$

which yields 0.38 µF.

I used a capacitance meter to select a cap that was marked 0.33, but measured 0.35. I figured that was close enough, since the reactance of a 0.35 cap is 7.6K, which is about 8% off the computed value — not enough for concern.

Just Double the DC Voltage, Right?

On the Digi-Key website, there are data sheets for both a Metallized Polyester Film (MPET) capacitor (EPCOS MKT) and a Metallized Polypropylene Film (MPP) capacitor (BC components MMKP 383). Both of them are offered at a value of 0.33 µF at 250 VDC. The MMKP 383 also comes in 0.36 and 0.39 values.

For the MPET cap at a 250 VDC rating, the maximum AC RMS voltage is 160 V. For the MPP cap at 250 VDC, the maximum VAC is 125 V RMS.

So far, it looks like the old "double the voltage" hack seems to work — at least it does until you look at higher voltages. According to the spec sheet for an MMKP 383, the 630 VDC cap is only good to 240 VAC RMS for frequencies below 5 kHz at $T_{amb} \leq 85°$.

What about frequencies above 5 kHz — say, for instance, 40 kHz? At that frequency, the maximum voltage on that 630 VDC cap drops down to 45 volts RMS.

So, what causes this difference between the DC and AC voltage rating? The answer is simple: When current flows into (or out of) a capacitor, some heat is generated (both in the metallic parts of the cap and in the dielectric).

When a direct current is applied to a capacitor, this heating happens only once because the current eventually stops. The capacitor has a chance to cool down.

With AC, each reversal of the current generates a little more heat. This continues until either equilibrium is reached or the cap goes into thermal runaway and self-destructs. It is this heating that makes the difference and, as the frequency goes up, it gets worse.

If you know the dissipation factor (DF) of the cap (also called the Tangent of Loss Angle or tan δ) and it is below 0.1% (1×10^{-3}) at the frequency that the cap will be functioning at, then it is probably safe to use a cap with a DC voltage that is double the in-circuit AC RMS voltage.

By the way, polyester (or mylar) caps typically have a DF greater than 0.1%, so they may not be the best choice for AC applications. Polypropylene is a better choice.

If you don't have any data on a particular cap, here is a saving grace: If it's going to fail, it will probably do so within a few days, especially if you elevate the temperature to around 75°C/167°F (85°C/185°F, maximum). So, you could breadboard the thing and then run it continuously for, say, a week. If it survives, then there is a good chance the cap will go the distance. In other words, do a "burn-in."

Disclaimer: Don't rely solely on the burn-in method to validate capacitors for an application where someone's life or health is dependent upon the reliability of the device.

My little night light has been staving off the dark for more than a month now, which gives me confidence that the thing will be functioning far longer than I will be.

About That Capacitor's Voltage

If you looked closely at Figure 3, you might have noticed that the voltage printed on the capacitor I used is 250 V — which is a DC voltage rating — yet the schematic shows a voltage of 160 VAC. Why? Well, if I were to tell the absolute truth, I would say that all the 0.33 µF caps in my parts bin were 250 V and I was too lazy to try and find one rated for AC. Okay, now you know.

However, doesn't that typify the hobbyist's quandary? An engineer usually has access to data sheets and samples and, when the design is put into production, the components chosen are purchased at quantity discounts.

The electronics weekend warrior rarely has access to such luxuries and generally has to rely on seat-of-the-pants reckoning.

I figured that — since the nominal peak voltage across the capacitor is really the peak AC voltage minus the combined voltage drops across the LEDs, R1, and the rectifiers — it would only be exposed to a peak voltage of:

$$169\ \text{V} - (20\ \text{V} + 470\ \Omega * 20\ \text{mA} + 1.4\ \text{V}) = 138.2\ \text{V}$$

This means my 250 volt cap is probably just fine, but — if you want to make absolutely sure this thing lasts "forever" — then see if you can find a cap that is actually rated for AC and that will fit inside the nightlight hood.

For more on this subject, see the sidebar.

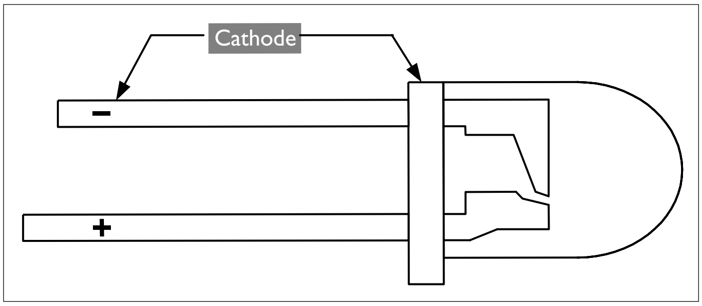


Figure 4. Identifying LED polarity.

Note: *If you DO use the "burn-in" method described in the sidebar, be sure to replace the LEDs with a resistor if you plan to elevate the temperature because — as I said before — it's not good to run white LEDs hot.*

Let's Build the Thing

This will actually be a retro-fit of a common 4 watt night light. If you don't have one lying around or lighting

Figure 5. All six LEDs joined in series.

the path to the bathroom, you can buy them nearly everywhere, just make sure it doesn't have a photo sensor that turns it off during the day.

Once you acquire the nightlight, unscrew the lamp and put it into a Zip-Lock™ freezer bag. After you put on eye protection, smack the lamp with a hammer to break the glass envelope. Then, using a pair of needle-nosed pliers, break out the rest of the glass. (Be careful not to cut yourself, of course.) You also might want to wear a pollen mask over your nose and mouth so that you don't breathe any of the glass dust that might be generated while you're doing this.

I also suggest that you remove the existing wires and replace them with copper. Solder didn't stick to the existing wires on the lamp I experimented with.

If you do replace the wires, I suggest you remove the existing lead from the metal lamp base (Figure 2). When you solder the copper wire there, make sure to leave a blob of solder that extends out as far as the original lead did.

Position the central wire so it is well away from the metal shell (e.g., right in the center) and then fill the base with some five minute epoxy (Figure 6).

After the epoxy is good and solid, screw the base into the night light (of course, while the night light is unplugged) and tighten it by pressing the needle-nosed pliers against the epoxy while applying a twisting motion.

Figure 6. Lamp base filled with epoxy.

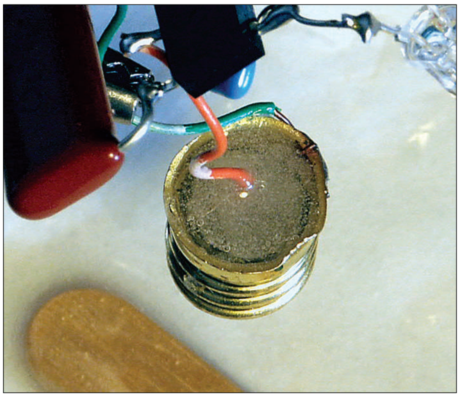
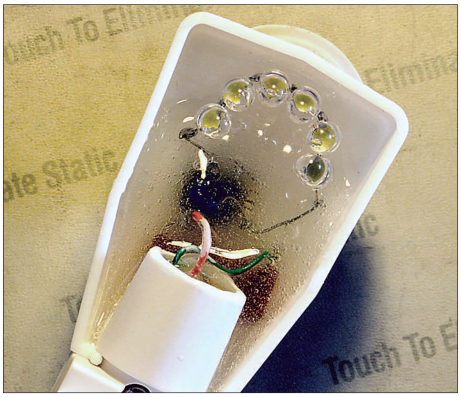


Figure 7. LEDs sealed in epoxy.



Try arranging the components in the hood of the night light to see if they all fit. Bear in mind that this circuit has no isolation from the hot side of the AC lines, ***so any part of it could deliver a lethal shock*** — even the circuitry on the "low voltage" side of the bridge rectifier — so make sure that all of the component leads are down low in the bowl of the night light hood.

Once you find an arrangement that works, solder the components together. Pay special attention to the polarity of the LEDs (Figure 4), making sure to connect anode to cathode

when daisy chaining them together (Figure 5). Also, be sure to get the polarity right when you connect the LED string to the DC side of the bridge rectifier.

Double check all of your connections and then solder the wires from the lamp base to the AC side of the bridge rectifier. These wires should be well separated; even if they are insulated. You definitely don't want these wires to short!

It's a good idea to test your handiwork before sealing it in epoxy. Put the night light on a nonflammable surface and then use an extension cord to put some distance between you and the DUT (Device Under Test). If the LEDs light up and there's no smoke or fire, then pat yourself on the back and proceed to the next paragraph.

Caution: Now that the night light has been energized, the dropping capacitor (C1) might have a large voltage across it. Discharge it through a 2K resistor before proceeding, making sure your fingers aren't in contact with the resistor's metal leads. Better yet, make a capacitor discharger by installing a 2K resistor in the middle of a ready-made test lead (e.g., one with alligator clips on each end) and, of course, insulate it with something like heat shrink.

Next, cut a white ping pong ball in half and make a notch in the edge of one of the halves to accommodate the wires that extend out of the lamp base. Test to see if the ping pong ball half will fit into the hood and completely cover the wires. If not, trim it a little more.

It's epoxy time again! Mix some up and pour it into the hood, making sure to cover all exposed conductors that won't be covered by the ping pong ball (Figure 7).

Also, avoid pouring epoxy on the fronts of the LEDs, as that will reduce the brightness of the night light.

Before the epoxy sets up, push the ping pong ball half into the hood, lining the notch up with the wires that supply 120 VAC from the base. Then, to make sure the ping pong ball half never falls out, mix up a little more epoxy and dribble it around the edges where the hood meets the ball (Figure 8).

Once the epoxy sets up, you are ready to go. Plug the thing in and relax your toes, for they will no longer need to fear the night. **NV**

Parts List

R1	470 Ω 1/4 watt resistor
C1	0.38 µF 160 VAC capacitor (see text)
C2	0.1 µF Monolithic ceramic capacitor
D1	1 amp 400 PIV full wave bridge
LED	1-6 super bright white LEDs

Figure 8. The half ping pong ball in place.

For Information About Capacitors

Plastic film capacitors and AC:
www.dei2000.com/tech_papers/ppc_1.htm

Why AC voltage is lower than DC voltage in a cap:
www.seacorinc.com/support/bullet8.asp

The properties of various capacitor dielectrics:
www.americancapacitor.com/Diel.htm

This is a nice article on the difference between Power Factor (Pf) and Dissipation Factor (Df):
www.quadtechinc.com/newsletter/035051.pdf

Circle #75 on the Reader Service Card.

by Gerard Fonte

Mr. E. Machine: The Enigma Machine — Part 3

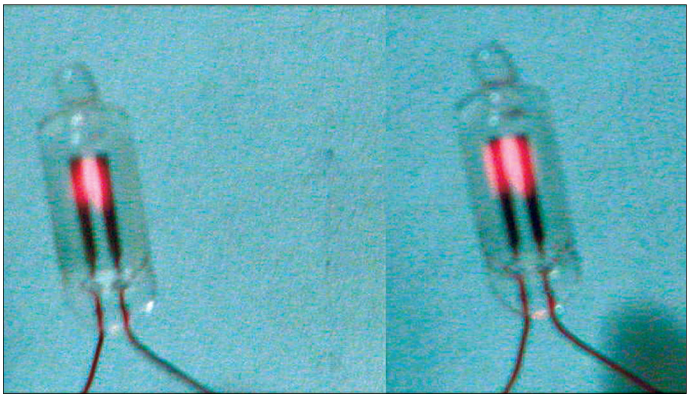
Repealing Ohm's Law

The Enigma Machine generates high voltage pulses that are safe to play with. In the first two installments, we saw how to build it and witnessed some of the more obvious strange effects. The vibration effect (where a dry finger brushes an empty soda can on the machine causes a vibration, but a damp or stationary finger does little) is probably the most apparent. This month, we'll look at some of the less obvious — but still very strange — effects. We'll also show how you can transfer an electrical charge without an electrical current or — to put that in another way — violate Ohm's Law.

Battery Operation

Last month, we closed by noting that battery operation greatly reduces or eliminates many of the Enigma Machine's effects. Why? The measured voltages and currents are identical. It was also shown that the effects returned to full strength if the tip of an oscilloscope probe (1X) touched either battery terminal. The oscilloscope had to be plugged in, but it did not have to be turned on. What's going on? (I should point out that identifying this problem was not trivial. I spent several full days tracking this question down.). Figure 1 is a composite image showing the difference between battery and AC operation with neon lamps. Unfortunately, this particular effect doesn't change as significantly as most of the others, but it is the only one that could be photographed.

Figure 1. This composite photograph shows the difference between battery and AC operation. Unfortunately, this particular effect has only a small difference. Other, non-visual effects are reduced by 50% to 75% when operating on batteries, even though the circuit measurements are identical.



The key to understanding this effect is to think of the Enigma Machine as a transmitter. Remember last month, when we saw how we could light a neon lamp a few inches away from the device? What do you need for an effective transmitter? Just like a receiver, a good antenna and ground will provide the best performance. There is no ground with the batteries. When you touch the oscilloscope probe to either battery terminal, you are providing an earth ground. That improves things greatly.

You say that the probe tip is not grounded, though, so how can that help? Actually, the probe tip is, indeed, grounded through a 1M resistor in the oscilloscope. You can verify this by using a 1M resistor and connecting it between the oscilloscope chassis ground and either battery terminal. The reason the positive battery terminal works as well as the negative terminal (which is the circuit ground) is that the impedance between the battery terminals is very low. It's on the order of an ohm or two. (If it wasn't, the battery wouldn't be able to supply much current.) Obviously, a one or two ohm difference in a million is not going to cause any measurable difference.

Isn't a megohm to ground too high to be useful? That depends on the impedance of the system. This system is single-ended and isolated. That's what makes it safe. It also means that there is a high impedance to everything outside of the case. So, a 1M connection to ground can be quite effective. If you use a 10X probe — which has 10M to ground — the effects are only partially restored. In fact, you can use this reduction in effect-strength versus resistance to ground to calculate the impedance of the Enigma Machine. I did some resistor tests and the impedance came out to be about 750,000 Ω.

More Simple Experiments

You can experiment with the effects of antenna loading. Have two different people try the soda can vibration experiment (refer to Part 2 in the July, 2004 issue of *Nuts & Volts*) at the same time. If someone is already holding the can or has a hand on the machine, the effects are reduced or eliminated. What happens to the vibration effect if you run a wire from the plate on top of the

machine to a grounded piece of metal?

Put the plate on the machine and put some headphones on. The large type with small speakers in the ear-cups work better than the Walkman-type ear-buds. Touch the bare end of the earphone connector to the plate. You'll hear the pulses quite well. How can you hear sound through a single wire? If you have the large earphones, try this: Put one finger on the plate and touch the headphone connector with a finger from your other hand. You'll also hear the pulses. (The ear-buds don't seem to work well with this experiment.) The energy from the machine is passing through your body and going into the earphone connector. Again, if there is no return circuit, how can you hear anything?

Put the plate on the machine and lower the lights. Hold a metal object in your hand (coin, pliers, etc.) and brush the metal plate. You'll be able to see small sparks, but you won't feel any shock.

Sprinkle a little pepper on the metal plate with the rate set to maximum. Hold a needle or pin and bring it close to a particle of pepper. It might just jump away. This demonstrates the ionic air currents created by the charge on the point of the pin. Unfortunately, this effect is rather weak. (Also, the microprocessor version must have R2 changed to 100K, as described in Part 2.) Try other light materials, as well.

Electrical Current

One of the more confusing aspects of this machine is the inability to measure a meaningful electrical current. Clearly, there is significant power because it can cause metal to vibrate. So, it seems reasonable that some current is flowing. It turns out that this may not be the case. In fact, there is strong evidence that shows that no electrical current flows.

Let's look closely at this because it's really important even though it's subtle. First, I estimated the expected voltage readings by looking at the signal shape and calculating the expected RMS voltage. I won't go into details here, but I came up with about 100 volts RMS (fastest rate with R2 at 100K). I opened the box and measured the actual voltage from the output of the coil to the circuit ground. I measured 78 volts with two different digital meters and 100 volts with an analog meter. These are pretty reasonable, considering the peculiar wave shape. Digital meters work differently from analog ones and the initial 100 volt value was a fairly crude estimate.

I then measured the current from the high voltage output to ground with two different analog meters and got a reading of 1.25 mA. These measurements were taken with DC meters, so I used a high voltage rectifier (20,000 volts PIV) in series with the meters. Therefore, the actual value should be twice 1.25 mA — or 2.5 mA. This is a reasonable value, as well. (The meters act as a short circuit, so the voltage drops to a very low value.) Only one of my digital

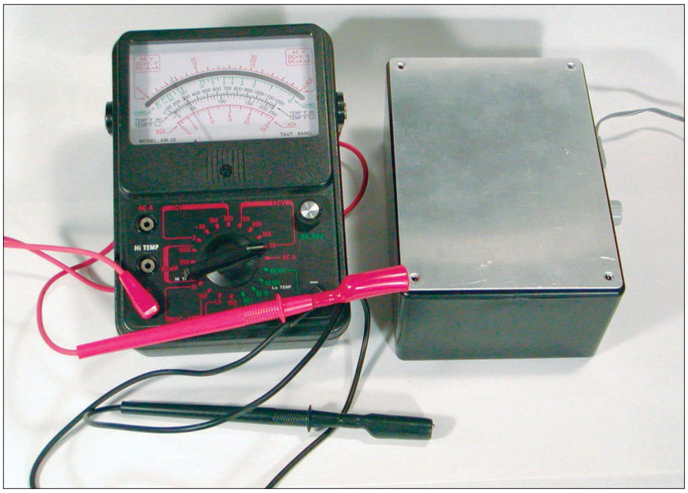


Figure 2. What's wrong with this photograph?

meters has a current scale and this meter failed to register anything as either an AC current or DC current (with the rectifier included). This is also not too surprising. The meter wasn't designed to measure pulses of thousands of volts on a current scale. I've seen digital meters choke on strange signals because of common mode problems and other things. So, this isn't too much of a concern.

Next, I closed up the box and placed the metal plate on top. Here's the first problem. The metal plate is obviously the hot connection, but where's the ground? I decided to use an earth ground. It was convenient and it seemed reasonable. I touched my oscilloscope probe (40X) to the metal plate (the ground lead was already grounded through the case) and saw about 1,400 volts — about 100 volts less than the internal measurement. This seemed reasonable, since there was 1/16 of an inch of plastic between the outside metal plate and the aluminum foil on the inside of the cover.

I then measured voltages from the metal plate to the oscilloscope chassis ground. Two meters said about 50 volts and the third said about 30 volts. With the increased impedance from the plastic cover, this wasn't unreasonable. However, the two meters that agreed with each other were not the same two that agreed with the internal voltage readings before. That's something to consider. I then tried to measure the current to ground. There wasn't any. All meters read 0.000 on any current scale with and without the rectifier included. The analog meter had a full-scale reading of 15 µA and no meter deflection was seen — very strange.

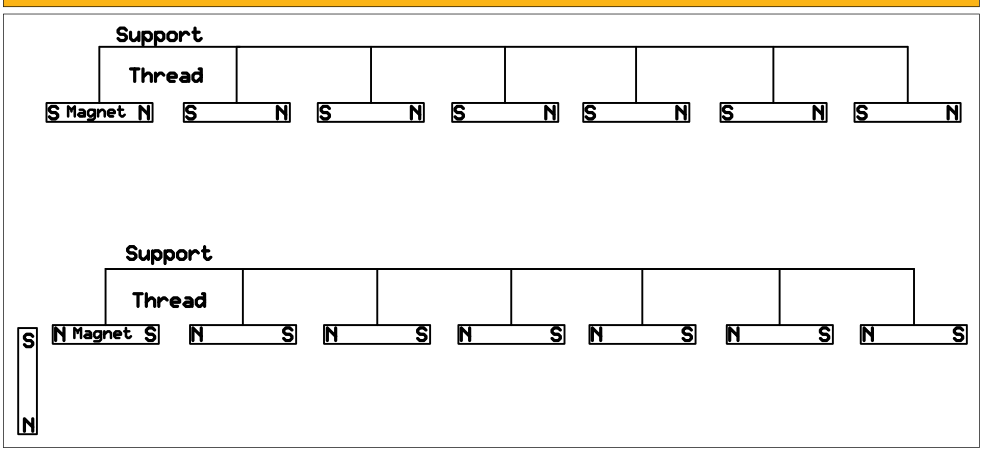
The digital meter that registered 50 volts is specified to have a 2M internal resistance. That was measured and verified. Ohm's Law says that, if there is 50 volts across 2 M, there must be 25 µA of current flowing. Even with the rectifier removing half of the current, there should still be over 10 µA of DC current flowing. This should be very evident on any of the meters. They all read 0.000.

Then, I noticed that a voltage reading was different. I looked and saw that the ground clip had fallen off the oscilloscope ground lug. That meant that there was only a single lead of the meter connected, but there was still a reading! For those who won't believe without seeing, take a close look at Figure 2. A single lead is connected to an analog meter and there is a significant pointer deflection. Digital overload can't be blamed on this because it's an analog meter. Digital meters do the same thing (but the actual readings are different). How can a meter show a voltage with only one lead connected?

It must be RF (Radio Frequency) radiation. Obviously, the frequency is not very high, but energy could still be radiating into the air. This means that the meter leads are acting as antennas. This was verified by touching the free lead's tip. The voltage reading increased.

Okay, so that explains why a single lead creates a voltage reading. We saw this before with the headphones. However, it doesn't explain why there is no current reading. There should be a current. Electrons can't flow without creating a current unless there is some mechanism where an electric charge can move without creating an electric current — that is, some mechanism where Ohm's Law fails.

Figure 3. You can propagate a magnetic field without actually moving the magnets. The "before" state is shown in the top diagram. If you bring another magnet close to any one of the series so that one rotates, then the rotation propagates through them all, as shown in the bottom diagram.



Chemistry to the Rescue

I won't go into all the details that led me to the following, but I realized that there was a possible mechanism where an electrical charge could be propagated through a substance without the movement of free electrons.

This method is the rotation of polar molecules.

Polar molecules have an asymmetric electrical charge. The total electric charge is zero, but the charge is lop-sided. One side of the molecule is electrically positive and the other is electrically negative. (It's sort of like a magnet with a north and south pole, which cancel out at large distances.) In ordinary matters — at room temperature — these molecules have more or less random motion and orientation, but — if an electrical charge is applied to one point — it will cause the molecules close to that point to orient themselves according to the electrical field. (Like charges repel and opposite charges attract.) It is very important to note that the molecules don't actually move. All that happens is that their electrical charge distribution changes. This causes adjacent molecules to orient, too, and it can go on and on. The application of a charge at one point is propagated throughout the material.

Look at Figure 3 as an analogy. Here, we have magnets suspended by threads so that they line up because of the magnetic field interaction. Now, however, rotate any one of the magnets. All the others will rotate, too. This is because the magnetic fields overlap. Like a bucket-brigade, changing the orientation of one changes them all. Even though the magnets remain in the same place, a magnetic field change is propagated through the entire length. In theory, there is no limit to how long or how far this propagation can go.

If this is true, there are a number of predictions to be made. The principal prediction is that different materials will have different "conductivities," depending on the polarity of the molecule (or dipole moment) rather than their normal electrical conductivity. So, I tested that. (Note, I will use quotes around "conductivity" to identify polar conductivity and no quotes to identify ordinary electrical conductivity.)

I chose a series of chemical variations of benzene. Benzene by itself is non-polar. By adding various chemicals to benzene the polarity changes. In this way, I had a series of basically similar chemicals with varying dipole moments. The chemical structures are shown in Figure 4. After running the experiment (with apparatus much more powerful than the Enigma Machine), I was able to graph the relationship between the polarity of the molecule and the "conductivity." The theory said that there should be a linear relationship.

Figure 5 is the graph. For now, ignore the peculiar benzaldehyde measurement. We'll discuss that later in more detail. The graph is, indeed, reasonably linear. The benzylamine dipole moment was estimated by me using a technique in my chemistry book. Even so, that value seems fairly close.

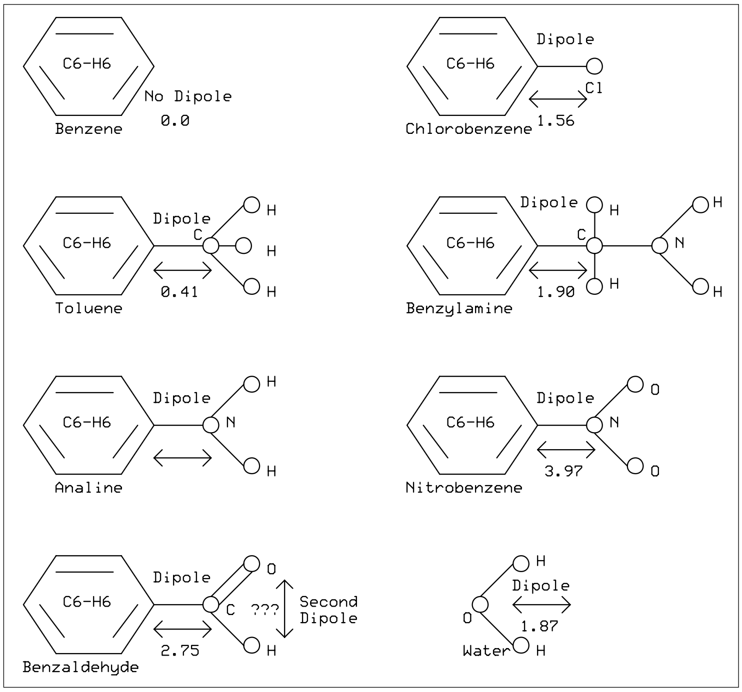


***Figure 4**. Here are the chemical structures of the tested materials. Note that benzaldehyde has a second, undetermined dipole moment that was initially overlooked.*

In addition, I tested carbon tetrachloride. It's a non-polar molecule and the theory predicts that it should match benzene (non-polar, too), which it does exactly. There is some residual "conductivity" in the non-polar chemicals. There are a couple of explanations for that, but I won't

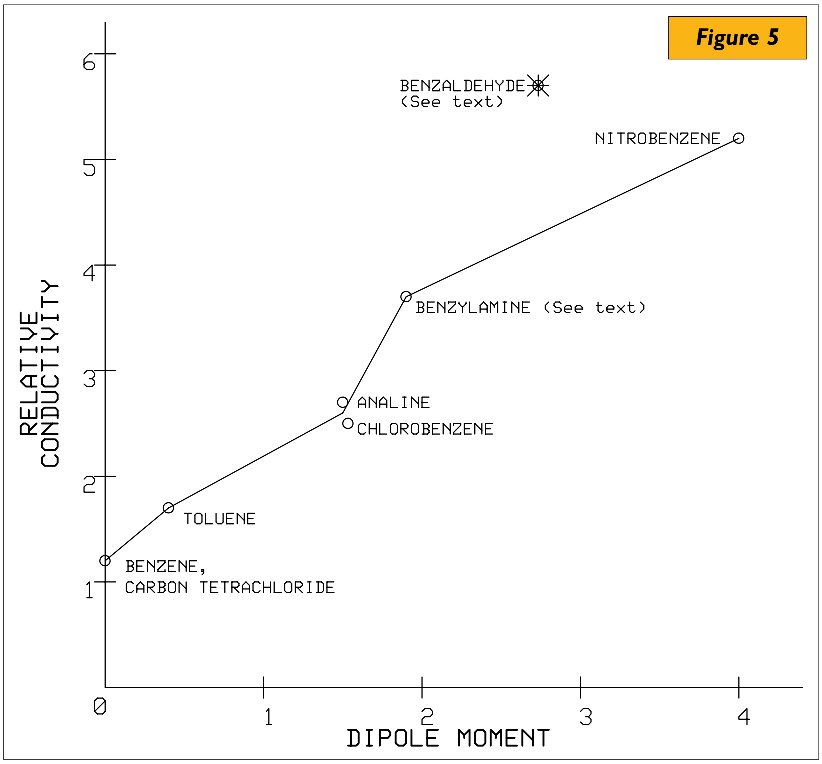


Figure 6. No seeds at all germinated in the energized group.

detail that here. So, this experiment seems to show that a charge propagation through polar molecules does occur.

However, what about benzaldehyde? It turns out that I screwed up in putting that on the test list. I didn't notice that it has a second dipole moment (with a value I couldn't determine). So, instead of having to rotate the whole benzene molecule, it only had to rotate a very small part of it. According to the prediction, it should be easier to rotate a lighter molecule than a heavier one, so the light one should have a higher "conductivity." That is also true. So, the screw-up was actually useful.

Some related comments are in order. The electrical conductivity is not at all related to the polar "conductivity" (another prediction that is true). For example, distilled water is a bad electrical conductor, but any water — distilled or otherwise — is an excellent polar "conductor." If you plot water on the graph (5.9 "conductivity" vs. 1.87 dipole constant), you will see that it doesn't fall on the line of benzene variations. Again, water is much lighter, so it's easier to rotate. However, closer examination suggests that there is more going on than just polarity and mass. It should also be noted that benzene and its variations are chemicals that have been shown to cause cancer. So, be extremely careful if you try to repeat these experiments. A safer series of chemicals is suggested.

Enigma Safety Notice

Please use common sense ...

1. This article deals with high voltage and high voltage effects. When built and used as described, it is felt to be completely safe. Improper use and construction can cause electrical shock.

2. Several experiments demonstrate effects that pass through the body of the user. Therefore, it is not recommended that anyone with a pacemaker or other embedded electrical device participate in these experiments, nor should it be used in very close proximity to any electrical equipment where electromagnetic interference could cause safety concerns.

3. Several experiments have shown subtle biological effects on plants after continuous exposure of days to weeks.

Complex Organic Reactions

It seems reasonable that rotating molecules in complex organic systems (living things) could lead to observable changes. I tried a number of simple experiments and most did nothing. However, one experiment showed very surprising results. This was with the germination of bean seeds (again with apparatus different from the Enigma Machine). Figures 6 and 7 show the experiment.

Two identical groups of seeds were planted. Both had a metal screen in the dirt. One screen was energized (Figure 6). The other was not (Figure 7). The results were very evident. Every seed in the energized group failed to germinate. The Chi-square statistical value of 10.77 was calculated. The 1% Chi-square confidence level is 6.64 and the 0.01% confidence level is 10.83. This means that there is only about one chance in 1,000 that the germination failure was due to chance alone. For reference, anything better than one chance in 20 is required for scholarly publications. I tried a similar experiment with the Enigma Machine and oat seeds, but there was no measurable effect.

However, I did get an effect with the Enigma Machine and bananas. My wife got some organic bananas that were very green — so green that, after several weeks, they showed no signs of ripening. I put two on the Enigma machine and two in a basket close by. After another week, the bananas on the Enigma Machine were clearly riper than the other ones. However, this is not very scientific and I only used four bananas, but it would be worthwhile for you to try.

Safety Question

This raises the question: Is the Enigma Machine safe? I believe so; otherwise, I wouldn't have published the design. Any biological effect requires continuous contact with the machine for days or weeks. The Enigma Machine is much less powerful than what was used for the other research.

Additionally, the pulse rate for the Enigma Machine is different. According to the American Conference of Governmental Industrial Hygienists (which defines workplace safety limits), "Occupational exposures should not exceed a field strength of 25 KV/m from 0 Hz to 100 Hz. For frequencies in the range of 100 Hz to 4 KHz, the ceiling value is given by E=2,500,000/frequency ... where E is the field strength in volts per meter."

The Enigma Machine generates low duty-cycle pulses of about 1,500 volts at up to 256 Hz. So, if you are more than a few inches away, the field strength is lower than that recommended (for continuous exposure). Additionally, the values are based on, "limiting currents on the body surface and induced currents." As we've seen, there is no current. Finally, "Certain biological effects have been demonstrated in laboratory studies at electric field strengths below those permitted in the TLV (Threshold Limit Value); however, there is no convincing evidence at the present time that occupational exposure to these field levels leads to adverse health effects" (from "TLVs and BEIs, Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices," 2003). So, use common sense with the Enigma Machine.

However, this raises a related question. While the Enigma Machine is safe, we've seen how strange and misleading some of the measurements can be. Are there other situations where safety is more of a problem? Do the mechanisms of polar molecule rotation apply to those ELF (Extremely Low Frequency) concerns that were well publicized a few years ago? Is it possible that these ELF measurements may be measuring the wrong things?

Figure 7. The control group showed significant growth.

We'll discuss these points next month. I'll also show some impressive, high power effects. Lastly, we'll see how Kirlian photography and the related life "aura" pseudo-science is completely explained with what we've already learned. **NV**

THE MAN WHO INVENTED THE FUTURE

BY MICHAEL BANKS

Who was Hugo Gernsback? The answer depends on whom you ask. "Gernsback published the first science fiction magazine!" a science fiction reader will declare. Ask an engineer and you might hear, "Gernsback ... wasn't he involved in early experiments with television broadcasting?" Others will recall Gernsback's radio magazines. A radio historian will tell you that Hugo Gernsback owned radio station WRNY, introduced the first home radio set (1905), and championed the cause of radio amateurs.

A scattered life, indeed, but with one with a focus: the future. Hugo Gernsback was the world's first futurist — one who not only speculated about the future, but also worked to make it happen.

Born Hugo Gernsbacher on August 16, 1884, Gernsback was the son of a vintner in Luxembourg. As a child, he became fascinated by electricity when a handyman at his father's winery showed him how to wire a battery to a bell to make it ring.

Gernsback almost immediately expanded his capabilities with battery powered telephone sets, lights, and buzzers. He wired the family home with telephone-intercoms and a 6 volt lighting system. He was soon installing door buzzers and intercoms in neighbors' homes and was commissioned to set up a complicated system of buzzers in a nearby convent.

When he was 10, Gernsback experienced a bizarre event. After reading American astronomer Percival Lowell's book about Mars, he was so overwhelmed by the possibility of life on the Red Planet that he fell into a two-day delirium, babbling incessantly about Martians and their technology. This obsession shaped his life.

Following his basic education, Gernsback was enrolled in a boarding school in Brussels. He mastered all he studied, including English. He read Western novels, including the works of Mark Twain, which fueled a desire to go to America.

Gernsback next studied electrical engineering in Germany, where he perfected a portable radio-telegraph transmitter and a high amperage, dry-cell battery that he was convinced would make him rich. In 1904, he bought a first class ticket to Hoboken, NJ, taking with him two models of his battery and $100.00 from his family.

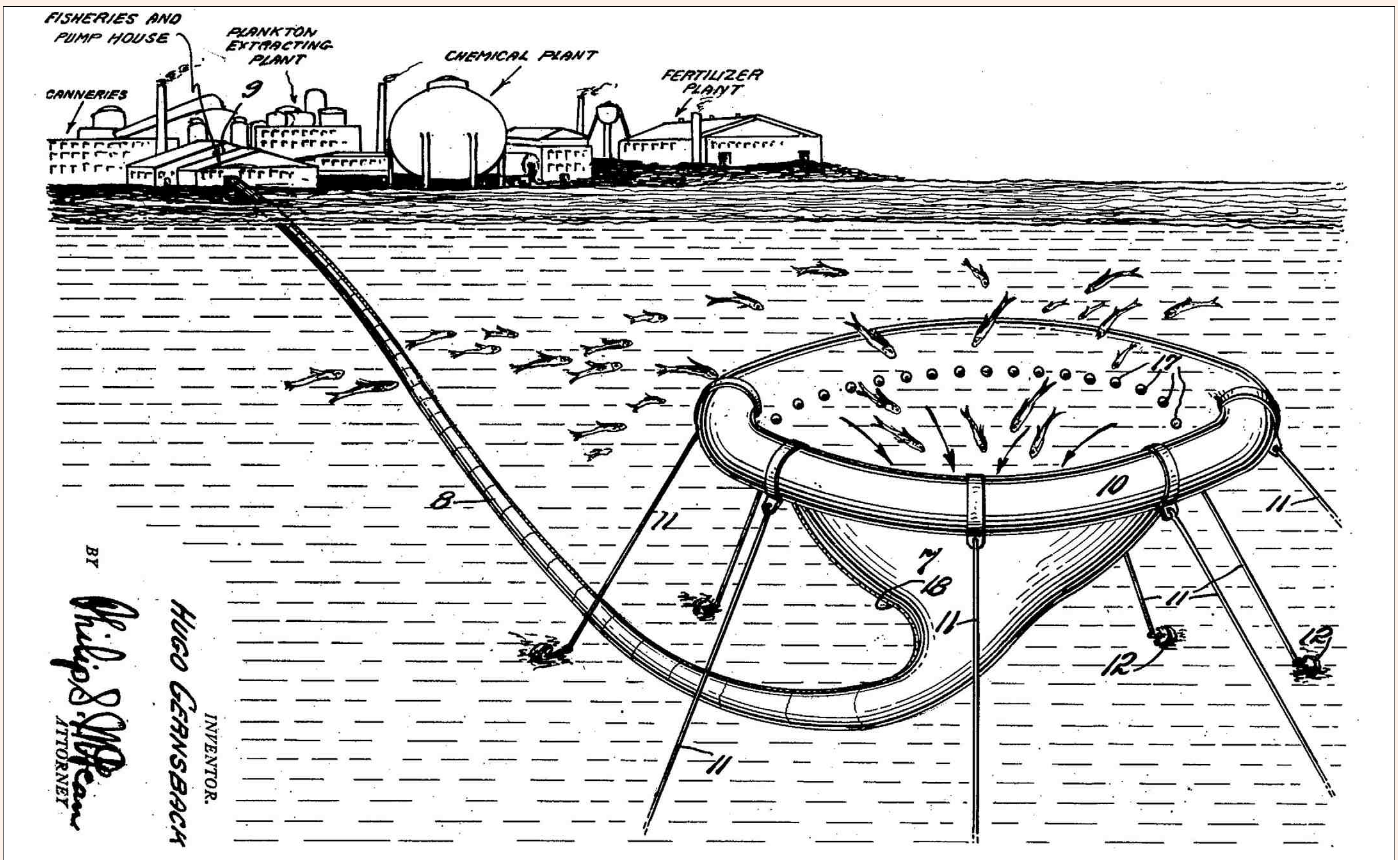
The young man made his way to New York, where he distributed business cards with the name "Huck Gernsbacher." (He borrowed the name from his favorite character, Huckleberry Finn). After receiving US patent #842,950 for his battery, he sold the rights to the Packard Motor Company.

Now flush with cash, Gernsback decided to build and market his portable radio transmitter. Unable to find the parts he had used in Europe, he ordered them from a German supplier, at which point it occurred to him that perhaps there was money in importing radio components. He found an investor/partner, Lewis A. Coggeshall, and they rented space in a building at 32 Park Place in New York, where they established the Electro Importing Company to sell radio components and electrical supplies by mail order.

Gernsback's spark gap transmitter came with a receiver and had a one mile range. Marketed as the "Telimco Wireless Telegraph," it sold for $8.50. ("Telimco" was derived from the company's name.) This was the world's very first home radio set.

Scientific American published an article about the Telimco in 1905, but sales didn't take off until 1906, when Gernsback placed ads in *Scientific American*, *Youth's Companion*, and *The New York Times*. The set was copied by competitors — but not before Gernsback sold Gimball's, Macy's, and Marshall Field on carrying it.

In addition to the Telimco, the company offered coherers, "Telimphones," spark gaps, wire, and batteries. Whenever



A patent drawing for one of Hugo Gernsback's many inventions — a "hydraulic fishery" — intended to solve the world's food problems.

possible, Gernsback presented radio as a wholesome activity; ads for the Telimco proclaimed that, "Wireless will keep your boy at home!"

Demand mushroomed. Within two years, the Electro Importing Company was sending its 64-page catalog throughout North America. (Even Lee De Forest shopped Electro Importing!) Gernsback didn't hesitate to flaunt his success, wearing tailor-made suits, expensive shirts, and a monocle, while affecting the manners and attitudes of European gentry. He dined at New York's most expensive restaurants and was seen at the best theaters. Not surprisingly, he soon married a young woman named Rose Harvey. She bore him a daughter in 1909. (He would marry twice more and father a son and another daughter.)

The Gernsback-Coggeshall partnership dissolved in 1908. January 1909 found Gernsback running this ad in *The New York Times*:

> Partner wanted in well-established electrical manufacturing business; good chance for right party; have more orders than can fill;
> only parties with sufficient capital need apply.
> H. Gernsback, 108 Duane St.

The ad was answered by a man named Milton Hymes. With the infusion of capital, the company moved its factory and 60 employees to 231 Fulton Street in New York and soon opened two retail stores.

Gernsback wrote lengthy tutorial articles for the Electro Importing catalog. This gave him the idea of starting a magazine for electrical experimenters, which he called *Modern Electrics*. The magazine quickly established itself as a cutting edge publication; the December 1909 issue carried an article by Gernsback titled "Television and the Telephot," which was the first instance of "television" being used in a technical article. (Gernsback maintained that a French author had used the term before him, however.)

Gernsback was publisher, editor, chief writer, and often ghost-writer of *Modern Electrics* and did the layouts and sold advertising. To further promote radio and his magazines, Gernsback established a *Blue Book of Radio* and the Wireless Association of America (WAOA). WAOA soon claimed 22,300 members and Gernsback worked to represent the interests of amateur radio operators in Washington D.C., helping shape the Radio Act of 1912.

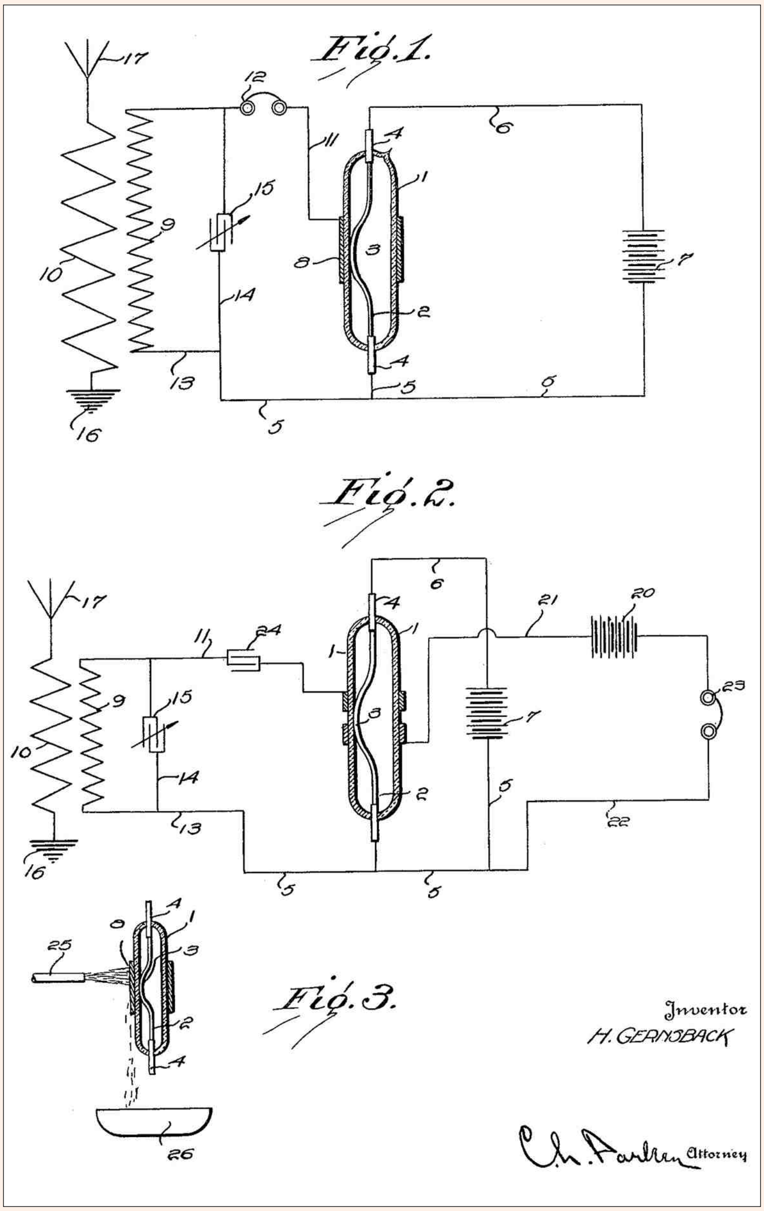
One day in 1911, Gernsback needed to fill some empty space in the issue of *Modern Electrics* he was preparing. Readers enjoyed his forecasts about the future of technology, so he decided to give them more of the same — in the form of an adventure tale set in the year 2660. He wrote only enough to fill the empty space and ended with a cliff-hanger.

The tale, titled "Ralph 124C41+" (a bit of wordplay) grew to 12 installments. (It was eventually published in book form and remains in print today.) Gernsback soon added science-oriented adventure tales to all his magazines — some written by Gernsback under pseudonyms.

A new magazine called *Electrical Experimenter* served as another platform for Gernsback to push the science of the future. Complementing this was an irregular series of more Gernsback science fiction stories, called *Baron Munchhausen's New Scientific Adventures*.

When the US government banned amateur radio at the beginning of World War I, Gernsback's radio business was nearly wiped out. He was stuck with $100,000.00 in radio parts that he could not sell — until he came up with a clever idea. He designed electrical kits based on the parts in his warehouse. Each $5.00 kit came with instructions and all the parts necessary to build a given device. Before long, thousands of experimenters were building such gadgets as "electric fish" and telephone sets. When

An "electric valve" designed and patented by Hugo Gernsback in 1921.



amateur radio was revived in 1919, Gernsback launched the first magazine devoted to radio, *Radio Amateur News*.

While Gernsback found it easy to describe his ideas in print, he developed few; details bored him and some ideas were too broad or impractical. For example, he proposed that automobiles be made extremely narrow, with one wheel in the front and one in the rear. Such automobiles, Gernsback said, would solve parking problems. Another space-saving idea was to eliminate cemeteries by launching the bodies of the deceased into space.

Still, he did have some practical ideas. He patented a new kind of variable condenser that operated on a compression principle; this one earned him some money. A radio speaker patterned after the human ear and several telephone-related inventions followed. (An oft-repeated tale about Powel Crosley "stealing" Gernsback's condenser is false. Crosley filed a patent for a "book condenser" in 1921. Gernsback filed the patent for the compression condenser in 1923.)

Also among Gernsback's ideas was a gadget called the "Ososphone," designed to enable the hard-of-hearing to hear through their teeth via bone conduction. Then, there was a ferris wheel with a twist; instead of merely rotating, it would roll down a track into the Atlantic Ocean, dunking and raising passengers in sealed cabins as it went. He patented this "submersible amusement device" in 1921, along with an idea for landing airplanes on the decks of ships or the tops of Manhattan skyscrapers (giant electro-magnets would insure safe landings. Neither made it to reality, nor did a gargantuan vacuum cleaner-like device designed to suck up schools of fish for commercial processing.

By 1924, Gernsback had started several more magazines: *Practical Electrics*, *Radio Amateur News*, *Your Body*, *Science and Invention* (formerly *Electrical Experimenter*), and *Radio International*. He also published technical books with titles like *Radios for All*.

In the course of promoting the future, Gernsback had become acquainted with many of the world's leading scientists. His position as a publisher gained the attention of Marconi, Goddard, Tesla, and even Edison. (He was in literal awe of Tesla, whose ideas he viewed as mankind's salvation. When Tesla died, Gernsback commissioned a death mask of him and published photos of it.)

With his Experimenter Publishing Company providing a healthy cash flow, Gernsback took the obvious next step and moved into broadcasting. Early in 1925, he and a partner, Robert W. DeMott, were granted a commercial broadcasting license and assigned the call sign WRNY. Transmitting at 1160 kilocycles, the station went on the air on June 12, 1925, from a studio in New York's Roosevelt Hotel. The 500 watt transmitter was located near Coytesville, NJ. Lee De Forest was among the inaugural speakers.

Gernsback also used WRNY to promote his ideas about the future with scientific lectures. Actually, it often seemed that he talked and wrote of nothing but the future and he was fond of making bold prognostications — many of which were accurate. Among other wonders, he predicted microfilm, computer dating, night baseball, cell phones, virtual reality, and flat-screen television. Conscious of his audience, he tempered speculation with articles such as "Electrifying the Holy Land" and "Radio Telephony and the Airplane."

Still, reader response to speculative material in his technical magazines had given Gernsback the idea that there might be a market for science-based fiction. He tested this idea with an all-fiction issue of *Science and Invention*. Readers demanded more and Gernsback decided to publish an all-fiction magazine called *Amazing Stories*. The magazine's motto was, "Extravagant Fiction Today ... Cold Fact Tomorrow."

Amazing Stories was difficult to categorize. The term "science fiction" did not exist; tales like Jules Verne's *20,000 Leagues Under the Sea* were referred to as "scientific romances" or simply "adventure." Gernsback decided that, because the fiction was scientific, he would call the genre "scientifiction." This evolved into the easier to pronounce "science fiction."

The first *Amazing Stories* was published in April 1926. Early on, it carried mostly reprints from the likes of Verne and Wells, but soon switched to all original fiction. Gernsback wasn't exactly generous to his writers, though. He offered payment as low as 1/4 cent per word for stories and was usually slow to pay. This cost him contributions from several noted writers.

Perhaps Gernsback's greatest technological achievement was in early television. In mid-August of 1928, WRNY began regular television broadcasts with a mechanical

A typical futuristic Gernsback magazine cover, this 1915 one depicted a satellite orbiting the moon.

Hugo Gernsback in his office, mid-1920s.

system devised by John Geloso of the Pilot Electric Company. The system used 24 inch, 48 line scanning disks that rotated at 240 rpm. Gernsback published plans for a receiver in *Science and Invention* and invited radio amateurs to tune in to daily five minute broadcasts. His newest magazine, *Television*, estimated that there were some 2,000 viewers that summer.

Just as Gernsback's publishing empire reached its peak, disaster struck. Like many publishers, Gernsback paid for printing the current issues of his magazines only after receiving the revenues from the preceding issues. A larger competitor convinced printers and other creditors to demand immediate payment, which forced Gernsback into bankruptcy. Unwilling to give up, he sold the Electro Importing Company and WRNY to stake a new publishing company.

The new magazines competed successfully with his old titles and he expanded with periodicals that reflected his scientific and sociological interests, as well as a few odd subjects, like risqué humor. A partial list includes: *Aviation Mechanics*, *Fotocraft*, *French Humor*, *Know Yourself*, *Motor Camper and Tourist*, *Popular Electronics*, *Science Wonder Stories*, *Scientific Detective*, *Sexology*, *Technocracy Review*, *Woman's Digest*, and *Your Dreams*. Books for electronics experimenters and professionals continued to come out under the Gernsback imprint, as did science fiction novels.

As an inventor, engineer, designer, businessman, writer, editor, and publisher, Hugo Gernsback's activities touched the lives of millions. It is safe to say that many thousands of today's broadcast and computer engineers and technicians were avid readers of Gernsback magazines and books early in their careers. The same can be said of science fiction fans.

Gernsback's accomplishments did not go unrecognized. He is widely lauded as the "Father of Science Fiction" (though "Science Fiction's Rich Uncle" is more accurate). The World Science Fiction Society's Annual Achievement Awards are called "Hugos" in his honor. He is also a member of the Science Fiction Hall of Fame, the Consumer Electronics Association's Hall of Fame, and has been similarly honored by other organizations. His homeland applauded his achievements when, in 1954, Gernsback was named an "Officer of the Oaken Crown" by Grand Duchess Charlotte of Luxembourg.

Hugo Gernsback went into semi-retirement in the 1950s and continued to promote the future — even publishing an annual booklet of predictions titled *Forecasts*, which he sent out as a New Year's greeting. He passed away in 1967 at the age of 83.

Gernsback Publications lived on for three decades. Appropriately, a Gernsback magazine was on the scene when the first personal computer made its debut in 1974; *Radio-Electronics* featured the Mark-8 minicomputer on the cover of its July 1974 issue. The last electronics magazine connected with Gernsback, *Poptronics*, lived on until January 2003, when it ceased print publication, but, in a way, at least one of Gernsback's publications lives on. After several name changes, Gernsback's first magazine, *Modern Electrics*, was eventually merged into *Popular Mechanics*.

On the science fiction side, while *Amazing Stories* and *Air Wonder Stories* have breathed their last, Gernsback's legacy lives on in every science fiction magazine published. Hugo Gernsback's real legacy, however, is the future. **NV**

Smith Chart Fundamentals

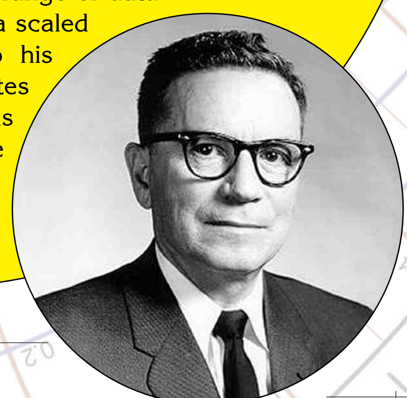
BY CHRISTOPHER HORNE

The Smith Chart is one of the most useful tools in radio communications, but it is often misunderstood. The purpose of this article is to introduce you to the basics of the Smith Chart. After reading this, you will have a better understanding of impedance matching and VSWR — common parameters in a radio station.

The Inventor

The Smith Chart was invented by Phillip Smith, who was born in Lexington, MA on April 29, 1905. Smith attended Tufts College and was an active amateur radio operator with the callsign 1ANB. In 1928, he joined Bell Labs, where he became involved in the design of antennas for commercial AM broadcasting. Although Smith did a great deal of work with antennas, his expertise and passion focused on transmission lines. He relished the problem of matching the transmission line to the antenna; a component he considered matched the line *to space.*[1]

Smith developed the first graphical solution in the form of a rectangular plot from his measurements of the maxima and minima voltages along the transmission line. He used a thermocouple bridge and voltmeter to make the measurements. The first graphical chart was limited by the range of data so he came up with a polar plot that was a scaled version of the first plot. According to his biography, his impedance coordinates were not orthogonal — which means perpendicular — and there were no true circles, but the standing wave ratio was linear. This chart closely



Phillip Smith — Inventor of the Smith Chart.

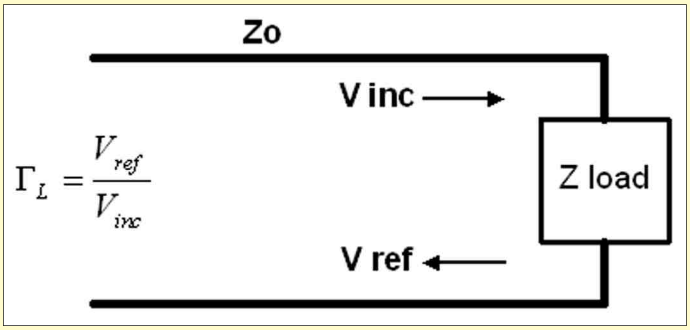


Figure 1. Impedance at the load.

resembles the chart we see today.

What Is a Smith Chart?

Although there are many computer programs[2, 3] and network analyzers that can solve impedance matching problems for you, a complete understanding of the Smith Chart is highly beneficial in understanding the nature of transmission lines. There is some algebra involved in understanding the basic transmission line equations, but — once you understand how to move on the graph — you can forget the math and just read the chart.

The Smith Chart is a polar plot of the complex reflection coefficient, Γ, for a normalized complex load impedance Zn = R + jX, where R is the resistance and X the reactance. A Smith Chart is utilized by examining the load and where the impedance must be matched. Sometimes, instead of considering the load impedance directly, you express its reflection coefficient, Γ_L.

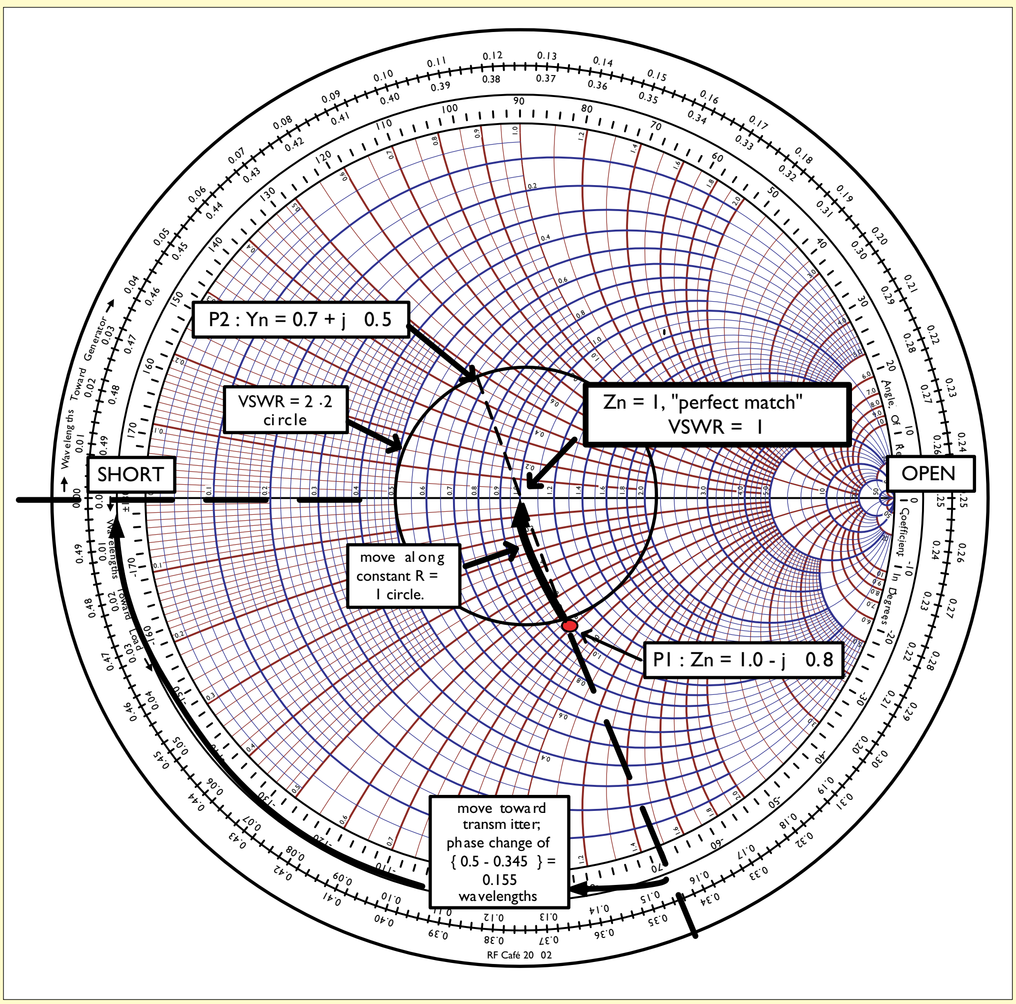
We know the reflection coefficient Γ_L is defined as the ratio between the reflected voltage wave and the incident voltage wave, as shown in Figure 1.

The reflection coefficient Γ_L is related to the load impedance Z_L and the system impedance Z_o as:

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o} = \frac{Vrefl}{Vinc}$$

There are resistance circles from 0 to "∞" Ω. The reactance curves on the top half of the chart are inductance curves; most notable are the 0.9 and 1.0 curves at the top that curve down to the right hand center. Polar means there is a real part — the magnitude of the impedance point (or Γ_L) and the phase of the impedance. On the Smith Chart, the phase is actually the distance in wavelengths along the transmission line — the outer-most circle. Once you plot the impedance point, other parameters — like Voltage Standing Wave Ratio (VSWR) or return loss — can be read off the Smith Chart.

Figure 2. Smith Chart showing antenna load impedance "P1," admittance point "P2," and path "P1-to-center" for a series inductor to obtain a "perfect match" at the center point.



The center of the chart (r = 1.0 and x = 0) is always a "perfect match," at least for a desired 50 Ω, but can be any impedance you want. For the common 50 Ω system, the center of the chart would be "normalized" to 1.0 units. All impedances are scaled relative to whatever characteristic impedance value you are working with.

VSWR can be depicted as a circle centered around the chart center (at "1.0"). One revolution around the VSWR circle is a one-half

wavelength. The reason once around is only half a wavelength is due to the addition of two waves — the forward and reflective waves on the transmission line. For example, your transmitter sends a forward signal (V_{inc}) and some of this signal is reflected back from the load as V_{refl}. Hence, the notion of “standing waves” comes from these two voltages. The smaller the SWR circle, the lower the return loss, and the better the impedance match. Understanding this principle proves that VSWR is constant along the transmission line. However, the resistive and reactive ratios do change along a line. Line loss increases VSWR by increasing the resistive component. This, too, is covered by the chart; read off the values by transcribing a line down to the scales at the bottom in decibels (dB) or voltage.

There are at least four other important points on the Smith Chart. Two of them represent an “open”: far right, where the resistive component is infinity, as well as a short and far left, where the resistive component is zero. The other two key points are at the extreme top and bottom points. At the top, you can see a “1.0,” which represents an impedance of +j*1.0, a pure inductor. At the bottom, you can also see a “1.0,” which represents an impedance of -j*1.0, a pure capacitor.

Every point in between represents the various combinations resulting from a mismatched condition and shows how far you are from the desired impedance — usually the center — and how to form the conjugate matching circuit. Simply plot the impedance of a load, then traverse the correct curves to reach the center (50 Ω). This is easier said than done, so here’s an example that concerns an antenna with an input impedance of 50 –j40 Ω, a 50 Ω transmission line, and a transmitter with a desired output impedance of 50 + j0 Ω.

A plot of the antenna load impedance is shown in Figure 2. The normalized load impedance is 1.0 - j0.8. The desired, normalized impedance is then 1.0 – j0.8 + j0.8 = 1.0. Using a compass, you can draw a circle centered on 1.0 with the radius extending to the point “P1.” From the real axis and the intersection of this circle, draw a vertical tangent line to the SWR scale at the bottom of the chart. In this case, the SWR is approximately 2.2.

The following is a very important procedure in using the Impedance Chart. Movement along constant resistance circles in the clockwise direction means that you are adding series inductance. Movement along constant resistance circles in the counter-clockwise direction means that you are adding series capacitance. In this example, we can reach the center point — a perfect match — by adding a series inductor. How do we determine the inductance value?

The equation for inductive reactance is $X_L = 2 * \pi * F * L$, where F is the frequency of operation. In the case of 21 MHz, $X_L = 2 * \pi * 21x10^6 * L * 50 = 0.8$ and, by rearranging terms, we arrive at L = 0.12 nH.

It is important to point out that the Impedance Chart can be used with admittance points. The point “P2” in Figure 1 represents the load admittance of 0.7+ j0.5. It is obtained by traversing the SWR = 2.2 circle one-half revolution and drawing a line bisecting the circle. You can move from P2 to the other points, as well, but you will be adding shunt elements rather than series elements in your matching circuit.

Impedance and admittance curves are used interchangeably when dealing with series and shunt circuit elements. The contours of constant resistance and reactance can now be interpreted as normalized conductance G and susceptance, S. In an Admittance Chart, movement along constant conductance circles in the clockwise direction means that you are adding shunt capacitance. Movement along constant resistance circles in the counter-clockwise direction means that you are adding shunt inductance.

Conclusion

The advantage of the Smith Chart is that it can solve transmission line problems very quickly; also, it forces you to understand how to match a load to the transmitter. If you practice using the Smith Chart to solve antenna or transmission line matching issues, you will be comfortable with all sorts of related problems. The Smith Chart can be applied to other RF devices, including tank circuits, filters, transistors, microstrips, and other microwave elements where a specific parameter — like impedance, power, or line loss — is needed for the RF system. NV

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

More Control From the Couch

With Bluetooth technology, remote control blues may be a thing of the past.

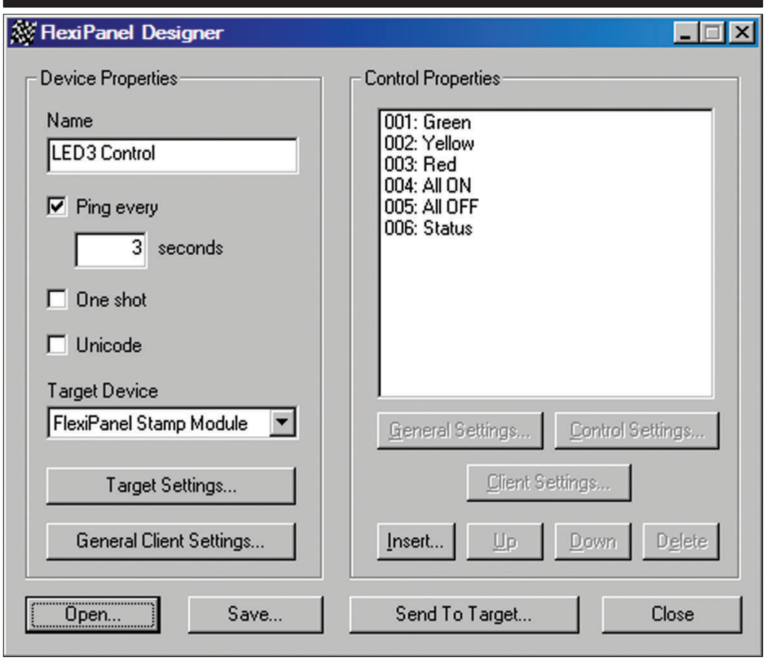
Yep, I'm still a real man, alright. I still live in the great state of Texas, drink milk right out of the carton, leave the toilet seat up, and — in addition to the five remotes I have to run the electronics in my entertainment center — I can now control anything else in my home from my Pocket PC. Yeah, buddy, I have enough control to make Tim Allen grunt with manly-man joy.

How is this possible from a Pocket PC? It's possible with FlexiPanel. The FlexiPanel architecture — available on many platforms — is an interesting approach to the client-server paradigm. The FlexiPanel server provides the interface (through a Bluetooth connection) that runs on the FlexiPanel client (a specialized browser application that runs on the PPC). The user is able to interact with the client interface and this interaction is made available to the BASIC Stamp microcontroller through a serial connection and (optional) status lines.

For our applications, the FlexiPanel BASIC Stamp Edition is the server and will connect to the BASIC Stamp using 19.2 kBaud serial connections with flow-control. The most popular client is for the Pocket PC, but more are available and many are planned. If you have the correct cell phone, for example, there is a client for it. How cool would it be to control things from your cell phone?

Let me start by saying that the BASIC Stamp side of this project is pretty easy — it's a straight serial connection and the system design is quite straightforward. The tough part is creating the client UI and — as I get lots of requests to cover that kind of thing — we're going to devote most of our time there. So, our project is dirt-simple: We're just going to control a few LEDs from our PPC. Not horribly exciting, but fraught with possibilities because — if we can control LEDs — we can control almost anything. I, for example, will be using this kind of project around Halloween (my favorite day of the year) to replace my keychain remotes for activating yard displays.

Figure 1. FlexiPanel Designer main window.



Creating the FlexiPanel Client UI

Okay, you know the drill: Plan your work, work your plan. Our plan, then, is to control three LEDs from a Pocket PC. Okay ... how, exactly? Well, let's make it simple and provide a button for each LED, where pressing the button will toggle the LED's state. Just for fun, let's add two more buttons: one for "All On" and another for "All Off." Of course, we'll also need some sort of feedback to the display, since we could be operating our device remotely. The range will depend on the Bluetooth module in your PPC, but could be up to 300 feet.

If you're like me, you probably have a quad-lined pad handy for sketching schematics. After doodling a bit and learning that the Pocket PC display is laid out like a playing card, I decided to put the three individual buttons across the top of the display, with the "All" buttons and status indication beneath them, using the full width.

With an idea of where we're going, we need to fire up the FlexiPanel Designer program. Figure 1 shows the program interface.

Author's Note: *Creating a custom UI for the FlexiPanel client is fairly involved, so I will not be discussing all of the features of the FlexiPanel Designer. I will, however, focus on those features that I've found are important for achieving the stated goal.*

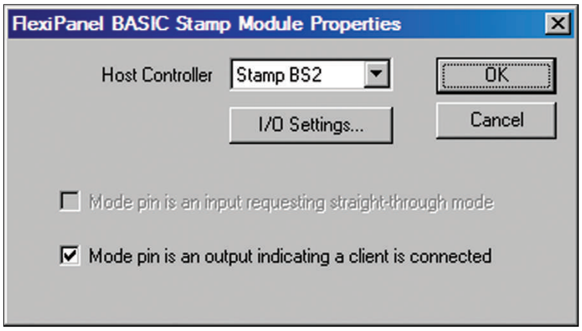


Figure 2. BASIC Stamp module properties dialog.

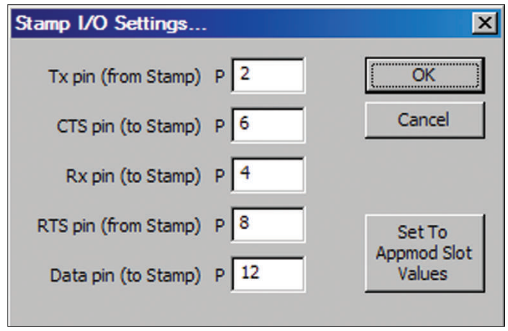


Figure 3. BASIC Stamp I/O settings dialog.

Starting with the Device Properties section, we'll give our client a name that gets displayed in the PPC title bar. Let's use "LED3 Control" — boring, yes, but obvious.

The next thing we need to do — specifically when our server controller is the BASIC Stamp — is to enable the Ping property. This will cause the server to verify the connection with the client. Three seconds is recommended by Hoptroff, makers of FlexiPanel.

In the Target Device drop-down, select FlexiPanel Stamp Module. The other choice is Simulation, which is useful when quick-testing UI designs; this works only if you have a Bluetooth-enabled PC. By selecting the BASIC Stamp as our target, the FlexiPanel software will generate a ROM image for the FlexiPanel server in the form of PBASIC source code. We'll get to more of this later.

Now, click the Target Settings button and you'll get the dialog box shown in Figure 2. This dialog lets us select the BASIC Stamp module used in our project. The reason Designer wants to know this is so that it can provide the correct $STAMP directive and baud mode constant for the generated source code. The other thing we'll want to check in this dialog is the selection that lets us use the Mode pin as a client-connected signal. By using the Mode pin to indicate the connection, our BASIC Stamp program is able to deal with its presence or, more specifically, when it drops. Some projects will need a "fail safe" behavior and using the Mode pin as a connection indicator makes this very simple.

With the BASIC Stamp module type selected, click on the I/O Settings button. This dialog (Figure 3) let us assign BASIC Stamp pins to the I/O point on the FlexiPanel module. Again, this is used for the generation of PBASIC source code and we're certainly free to modify the connections later if we need to.

Alright, enough of the preliminaries, let's get going with some controls. In the Control Properties section, click on the Insert button. This will bring up the Insert Control dialog (Figure 4). Select Button and then click OK. Since this is a new control, you'll be presented with the General Control Settings dialog (Figure 5). Change the name property to "Green" (We'll use this button to toggle our green LED.) and — for some pizzazz — check Preferred Color and enter the values 0, 255, and 0. After clicking OK, you should see the new button in the controls list.

Finally, we need to manually place and size the button. If we don't, the button will be a half screen wide and about 57 pixels tall; this is the standard button size for the FlexiPanel client. That's a bit chunky in my opinion, so let's fix it. In the Control Properties section, click on Client Settings and then click on Pocket PC Settings. With the Client Setting dialog (Figure 6), we can specify the attributes for the control. In my projects, I have found that the size, position, and page attributes are important to specify; the others can be left as is.

Using the steps we just covered and the information in

Figure 4. Insert control dialog.

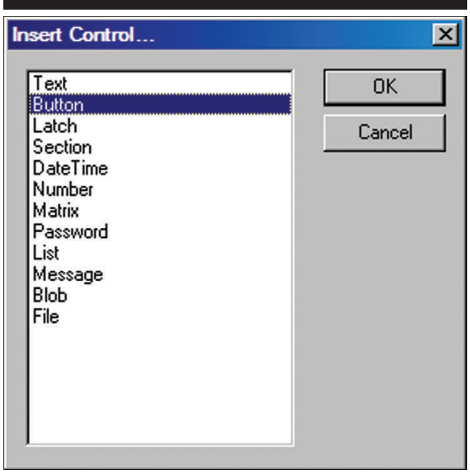
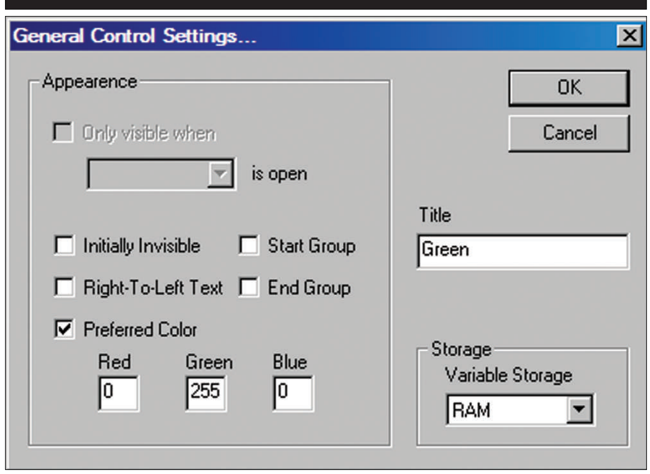


Figure 5. General control settings dialog.



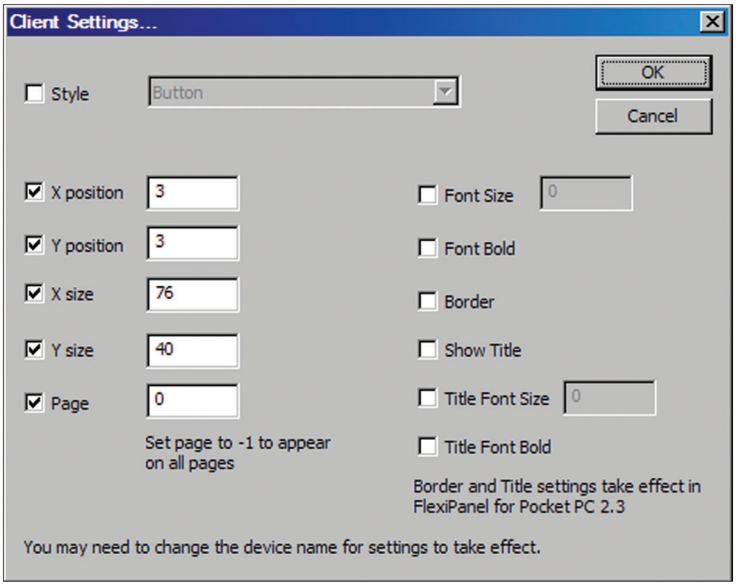


Figure 6. Control client settings dialog.

Control	Title	R-G-B	X_{pos}, Y_{pos}, X_{size} x Y_{size}, Page
Button	Green	255-0-0	3, 3, 76 x 40, 0
Button	Yellow	255-255-0	82, 3, 76 x 40, 0
Button	Red	0-0-255	161, 3, 76 x 40, 0
Button	All On	Default	3, 46, 234 x 40, 0
Button	All Off	128-128-128	3, 89, 234 x 40, 0
Text	Status	Default	3, 132, 234 x 40, 0

Table 1. Control client settings values.

Table 1, add four more buttons to the project. Finally, add a Text control. In the Text Control Properties dialog (Figure 7), enter "Status: ???" in the Initial Text field. What you should see is that — when you increase the length of the Initial Text field — the Maximum Length field will automatically update. The value in the Maximum Length field should always be one greater than the longest string to be displayed; the extra byte is a terminating zero. Make sure that Modifiable is not checked. The status string is an output only and we don't want the user to change this on the client screen.

Before we forget or are struck with one of those inconvenient power outages, click the Save button and give the file the name "LED3_Panel.FxP." (Note that you need to manually add the extension — but this may change in future versions of the Designer.)

Targeting the BASIC Stamp Microcontroller

With the client interface designed, we can move on to the next phase of the project, which is the BASIC Stamp module's interaction with the FlexiPanel server. The Designer program actually does a nice chunk of the work for us. Before exiting Designer, click the Send to Target button. A dialog that shows server resource allocation will be displayed — just click OK to move past it. We'll now be presented with a standard Save As dialog for the PBASIC program. You can use the default name (same as project) if you'd like; just be aware that, if you change the name of the program, you need to add the correct file extension.

If you haven't already done so, start the BASIC Stamp Editor and find the file we just saved. When you open it, the first thing you'll be struck by is the large **DATA** table. This is the ROM image for the server and is actually downloaded by the BASIC Stamp module. For small programs, we can leave the ROM image and loader in our control program. For bigger projects, we'll want to create a control that is separate from the loader.

Before we can run the program, the FlexiPanel server needs to be connected to the BASIC Stamp module. The FlexiPanel is conveniently designed to plug into the AppMod header on a Parallax BOE, but — if you don't have one — you can plug it into a standard breadboard and make the connections with hookup wire. If you're using the BOE AppMod header to hold the FlexiPanel module, be very careful with alignment. The Bluetooth radio and microcontroller will face the breadboard area and the module will plug into the left side of the AppMod header — the pins

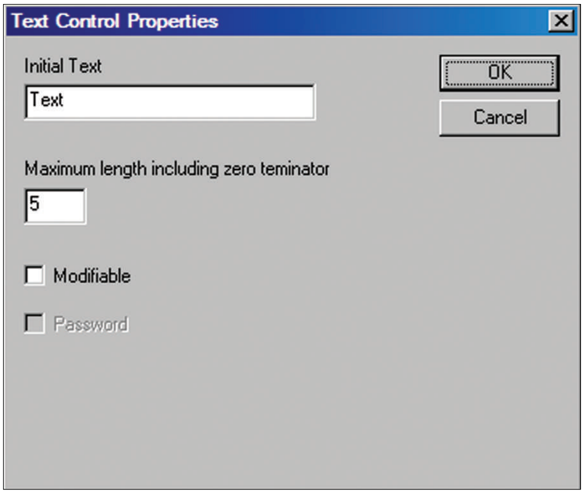


Figure 7. Text control properties dialog.

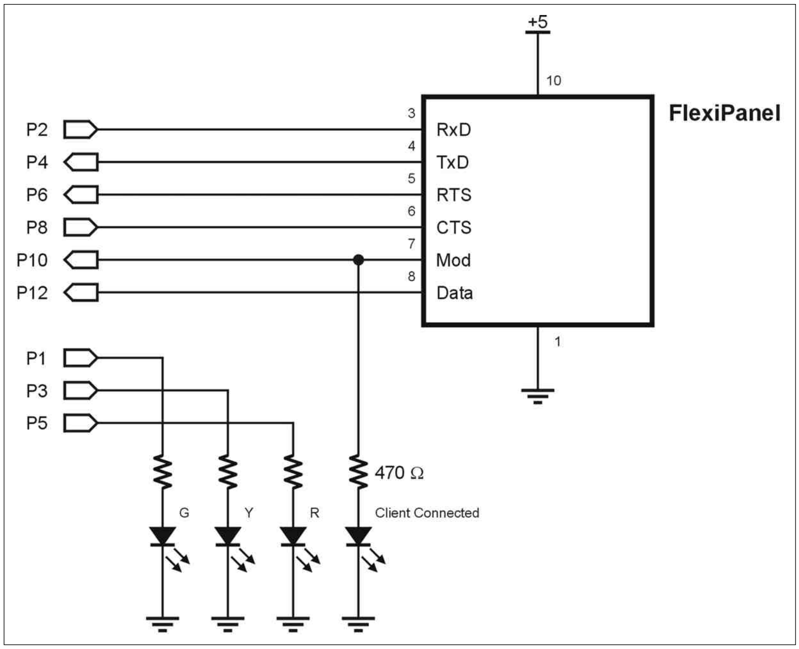


Figure 8. Project schematic.

marked Vss, P0, P2, P4, etc. The schematic for the project circuit is shown in Figure 8.

When everything is connected and powered up, run the program generated by the FlexiPanel Designer. What this will do is download the ROM image for the client to the FlexiPanel server. At this point, no other code is active, so we'll just get the controls, but won't be able to interact with them. When the FlexiPanel download is complete, the **DEBUG** window will display "Acknowledge: ROM." At this point, we can connect the client.

Make sure the latest FlexiPanel client is installed on your Pocket PC and then run it (from the Programs menu). Click the Connect button and you'll see the Bluetooth Console screen, as shown in Figure 9. Now, you probably won't see an icon for LED3 Control at this point, so click on the refresh button at the bottom of the screen. This will cause the PPC to search for other Bluetooth devices. When the LED3 Control icon appears, click it and — after a moment — you should see a screen with buttons laid out, as seen in Figure 10.

Once we're satisfied with the look of the layout, we can modify the PBASIC code to interact with the client controls. You'll see that Designer does a lot of the work for us, providing useful definitions and snippets of code that we can easily adapt for our own use. As I write, I am working with version 2.2 of the Designer and I fully expect future versions to add even more conveniences.

One of the changes I make to the auto-generated code

is a progress indicator for the ROM image download process. This can take quite some time with complex interfaces and the progress indicator lets me know things are moving. In an embedded application that doesn't have access to the **DEBUG** terminal, I would consider using an extra I/O point as a "Loading" indicator. Here's my final version of the loader:

```
DEBUG CLS, "Programming ROM...", CR
SEROUT TX\CTS, Baud, [$81, $31]
FOR idx = 0 TO $30F
  DEBUG CRSRX, 0, DEC idx, " of ", DEC $30F
  READ (FxpROM + idx), cData
  SEROUT TX\CTS, Baud, [cData]
NEXT
DEBUG CR, CR, "Awaiting acknowledge...", CR
SERIN  RX\RTS, Baud, [STR text\3]
DEBUG "Acknowledge: ", STR text\3, CR
```

After the **DEBUG** window is cleared, the programming command ($81) is sent to the FlexiPanel module, along with the number of 16 byte blocks to expect. Note that flow-control serial communications are used.

This is required, as the FlexiPanel module has to handle communications with the BASIC Stamp module, as well as the Bluetooth radio module.

A **FOR-NEXT** loop handles dumping the ROM image to the FlexiPanel server. What I added was the line that shows the current progress of the download. At the end of the loop, the module will respond with "ROM" to indicate that we're ready to go.

In this project, we're taking advantage of all FlexiPanel connections. One of those connections — as specified in the Designer — is the Mode pin. We've told the FlexiPanel module to use this pin as an output and an indicator when the client is connected. You can see in the schematic that an LED is hung off this output and it is also connected to P10 on the BASIC Stamp module. Here's the code that monitors that pin:

```
Get_Client:
  DEBUG CR, "Waiting for client...", CR
  DO : LOOP UNTIL (HasClient = Yes)
  DEBUG CLS,
        "Client is Connected", CR,
        "Use buttons to toggle LEDs"

  GOSUB Update_Status
```

The only work is the **DO-LOOP** line that waits for Mode output (called HasClient in our program) to go high. When it does, we can update the client with the current status of the LEDs. When first run, the LEDs will be off, of course, but that doesn't mean that we can't disconnect and then reconnect later. Let's see how to send information to the text control of our client:

```
Update_Status:
  text(0) = "." + (25 * OUTS.LOWBIT(GrnLED))
  text(1) = "." + (43 * OUTS.LOWBIT(YelLED))
  text(2) = "." + (36 * OUTS.LOWBIT(RedLED))
  text(3) = 0
  SEROUT TX\CTS, Baud, [SetData, ID_Status,
                        "Status: ", STR text\4]
  RETURN
```

This code looks a little trickier than it is — its purpose is to display the current state of the LEDs, using a dot for off or the first letter of the LED color for on. Let's just go through the green LED. If that LED is off, the OUTS bit that controls it will be zero, hence the expression in the parenthesis will evaluate as zero. When the LED is on and the OUTS bit for the green LED is one, the expression in the parenthesis will evaluate as 25. Yes, the BASIC Stamp can actually evaluate the expression "." + 25. It can do this because the "." is represented by its ASCII value (46) internally. So, when the green LED is on, the array element called text(0) will be assigned a value of 71 — the ASCII value for 'G'. Once the status string is constructed (along with a trailing zero), it is transmitted to the FlexiPanel using the SetData command.

Now, I'm betting that some of you are wondering why the use of the PIN definition for LED control outputs didn't help us much here. The reason is that the compiler will only evaluate PIN definitions as OUTx when the pin name is on the left side of an expression, but — when it's on the right — it will be evaluated as an input. When used as an index value — as in the code above — it will also evaluate as a constant. In the end, the compiler will evaluate OUTS.LOWBIT(GrnLED) as OUT1.

Okay, the display is updated; now, we can wait for some input from the user and then deal with it accordingly. The Data pin from the FlexiPanel module will go high when a control on the client has changed. When that happens, we will ask the

Figure 9. PPC Bluetooth console.

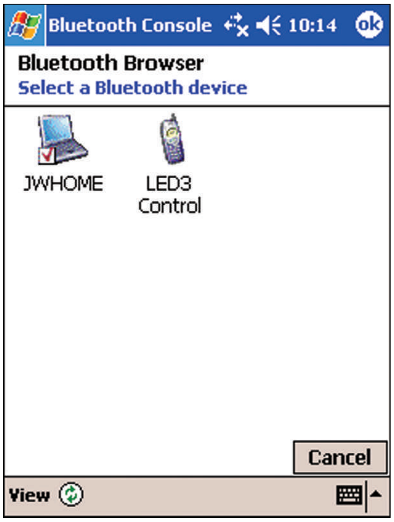
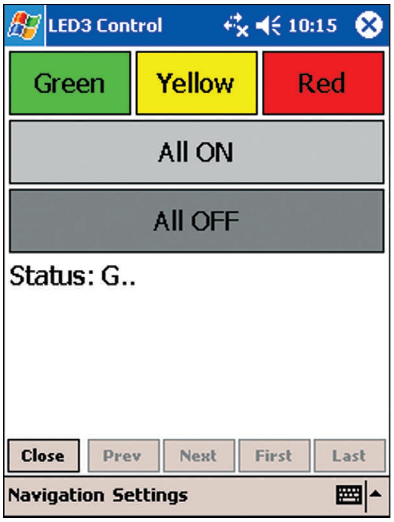


Figure 10. FlexiPanel client.



client which control changed. Here's how we do that:

```
Main:
  DO
    IF (HasClient = No) THEN Get_Client
  LOOP UNTIL (HasData = Yes)

Get_Changed_Control:
  SEROUT TX\CTS, Baud, [GetMod]
  SERIN  RX\RTS, Baud, [ctrl]
```

The initial **DO-LOOP** in this section is set up to wait for the HasData line to go high. Inside the loop, we can check the HasClient line to make sure that it hasn't dropped. In other applications, we could also put our normal "background" code in this loop.

When a control is changed on the client and the HasData line goes high, we'll drop out of the loop and then transmit the GetMod instruction to the FlexiPanel. The module will reply with the ID number of the control that changed.

The next listing shows how to handle a couple of the controls; the rest are identical, so the code has been removed for clarity. The **SELECT-CASE** structure lets us jump right to the code for the changed control. In the case of FlexiPanel buttons, we need to poll them for their status. While this may seem redundant (since the FlexiPanel already told us that the button had changed), it's quite useful, as the client will hold onto the button press until we have the opportunity to read the button. When we do, the "pressed" status will be cleared.

A value of $FF (aliased as Pressed in the program) tells us the button has indeed been pressed. For the single LED buttons, we use the pressed indication to toggle the LED status. For the "All On" and "All Off" buttons, the handle code follows the button function. When the button is dealt with, we update the display and go back to the top where we wait for another user input.

```
Poll_Control:
  SELECT ctrl
    CASE ID_Green
      SEROUT TX\CTS, Baud, [GetData, ID_Green]
      SERIN  RX\RTS, Baud, [cData]
      IF (cData = Pressed) THEN
        TOGGLE GrnLED
      ENDIF

    ' snip

    CASE ID_AllOff
      SEROUT TX\CTS, Baud, [GetData, ID_AllOff]
      SERIN  RX\RTS, Baud, [cData]
      IF (cData = Pressed) THEN
        GrnLED = IsOff
        YelLED = IsOff
        RedLED = IsOff
      ENDIF
  ENDSELECT

  GOSUB Update_Status
  GOTO Main
```

Additional Resources

Société HOPTROFF — **www.hoptroff.com**
FlexiPanel — **www.flexipanel.com**

You Have the Control

Let me be honest and say that we've gone through — at a reasonably quick clip — what is, in fact, a fairly complicated product. This is the reason I kept the BASIC Stamp end of things simple. What I encourage you to do is load up the project files (downloaded from the *Nuts & Volts* website — **www.nutsvolts.com**) and play with them to get the hang of things. If you don't have a Bluetooth connection on your PC, you can add one with a USB-Bluetooth adapter. (I use the DBT-120 from D-Link.) This will help the interface design cycle by using Simulation as the target for the Designer. In this mode, the client interface is downloaded from the PC and interface messages from the client are displayed in a dialog.

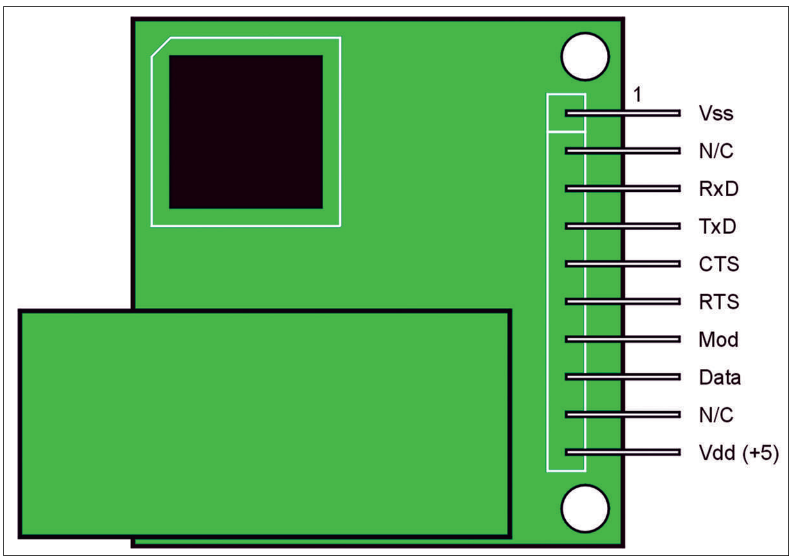
Spend some time with this — it may take a few days to get the hang of things, but I think it's worth it. Keep in mind that the FlexiPanel is a new product, so we can certainly expect improvements as more customers put it to use in various applications. I have certainly found the folks at Hoptroff to be very open to ideas and suggestions and helpful when I was in a pinch. I'm sure you will too.

Okay, it's your turn ... now there is no need to get up from the easy chair to turn something on or off. What will you control in your home? I have a pretty long list for mine ...

Until next time, Happy Stamping. **NV**

Jon Williams
jwilliams@parallax.com
Parallax, Inc.
www.parallax.com

Figure 11. FlexiPanel module connections.



Approaching the Final Frontier

Near Space

Temperature Sensors for the Hobo Data Logger

There are times when you would like to record temperatures. A data logger like the HOBO makes a great platform for this purpose. Onset — the manufacturer of the HOBO — even produces a line of sensors for recording temperature data. The directions that follow are for those who wish to make a temperature sensor for their HOBO data logger, rather than purchase one.

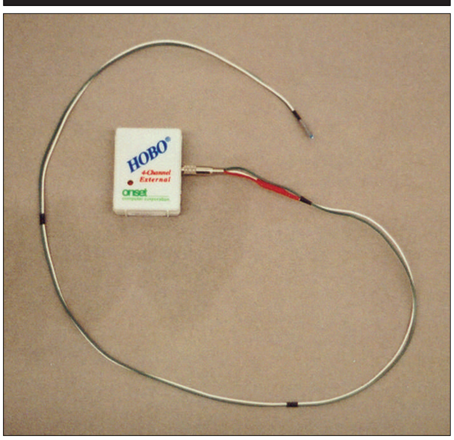
Goals

This month, we are going to make one (or more) temperature sensors for a HOBO data logger with external channels. The work doesn't end there, however. To turn the data our sensor records into the readings we require, we'll need to determine the equation that calculates the temperature from recorded voltage readings. From there, we will produce a chart of temperatures versus elapsed time.

Required Materials

- HOBO data logger with external channels
- 3/32" (2.5mm) stereo jack
- #24 AWG stranded wire (red, green, and white are the three suggested colors)
- A 51K resistor (1/8 or 1/4 watt) DMM
- A 10K thermistor (RadioShack part number 271-110A)
- Small diameter heat shrink tubing (1/8" and 1/4" are recommended)
- MS Excel spreadsheet or one of similar capabilities

Figure 1. HOBO and sensor.



About This Project

Like a photocell, a thermistor is a variable resistor. In the case of the thermistor, however, its resistance varies according to its temperature, as opposed to light intensity, as is the case for the photocell. For a typical near space (NS) mission, the thermistor described in this project will vary its resistance from 8.3K at 30° C (86° F) to 320.2K at –50° C (-58° F). The circuit used in this project is a voltage divider (two or more resistors in series).

The HOBO provides the supply voltage (2.5 V) for the input side of the voltage divider. The ground is located at the opposite end of the fixed resistor. The voltage measured between the thermistor and the fixed resistor indicates the temperature of the thermistor. It's the voltage drop across the thermistor that is being recorded by the HOBO.

In choosing the value of the fixed resistor, I wanted to maximize the range of the voltage drop across the thermistor for the typical temperature range experienced on an NS mission. I entered several temperatures and thermistor values into a spreadsheet. Then, I created a column for calculating the voltage drop across the thermistor based on a fixed resistor under test.

A final column indicated the amount of variation in voltage drops between the warmest and coldest temperatures expected. The range maxed out with a fixed resistor of 50K. The reduction in voltage range was minimal with resistors a few kΩ more or less than 50K. The 51K resistor is the closest standard resistor value, so I selected it for the circuit. The procedure we will follow is to, first, make and test the temperature sensor and, second, determine the temperature equation particular to your sensor.

Making the 3/32" Stereo Jack

These directions will make a single temperature sensor. Repeat them for any additional sensors.

Of course, we will first have to determine how far from the HOBO the temperature sensor must reach. In an NS application where the HOBO resides inside the NS craft and the thermistor may be placed outside, a length of two feet should suffice. Then, cut a two-foot length of green and white wire and a shorter, three-inch length of red wire. The red wire is much shorter because the 51K resistor will remain inside the NS craft and close to the HOBO. Now, strip about 1/8" of insulation from one end of each wire and lightly tin each stripped end.

Open the housing on the 3/32" stereo jack. Notice that the stereo jack has three solder pads. They are for the tip, ring, and base sections of the jack. Be sure you can identify which solder pad is for which section of the jack. Lightly tin each solder pad of the stereo jack and solder the wires to the following pads: white to the jack, white to the tip, red to the ring, and green to the base. You may want to slide some small diameter heat shrink tubing over the white wire where it is soldered to the jack tip.

At this point, it's a good idea to take a break and do some Quality Assurance. When you've done this, make sure the connections are good (mechanically strong and electrically conducting). Tug on each wire to make sure they don't pull off too easily. Then, strip a little insulation from the free ends of each wire and use a DMM in the continuity setting to measure for continuity between the end of each wire and the 3/32" jack.

You'll need to make sure there are no shorts between the wires soldered to the solder pads of the jack.

Use the DMM to verify that there are no shorts between the wires. You may want to squirt a little (very little) hot glue over the soldered jack. Finally, slide the jack cover over the 3/32" jack.

Finishing the Sensor

Okay, back to work. We'll finish the sensor by first stripping 1/4" of insulation from the free end of the red wire and tinning it. Then, cut both leads of the fixed resistor to 1/4" and tin them. Slide a 1/2" long piece of 1/8" heat shrink tubing over the red wire and place one lead of the resistor in contact with the tinned red wire. Now, heat the two wires with a tinned soldering iron and solder the two together.

After the joint cools, slide the heat shrink over the soldered connection and shrink. Next, lay the resistor against the white wire and mark where the remaining lead of the resistor lays against the insulation of the white wire. Carefully strip insulation from the white wire at the marked locations. Now, twist the lead of the resistor once around the white wire and solder them together. Of course, slide 3/32" diameter heat shrink over the soldered resistor and white wire.

Now, trim the white and green wires to the same length and strip 1/4" of insulation from the ends of the white and green wires before tinning the ends of the white and green wires. Cut several short pieces of 1/4" or 3/32" heat shrink tubing and slide the heat shrink over both the white and green wires. This heat shrink consolidates the green and white wires into a cable.

Cut two pieces of 1/8" diameter heat shrink tubing to a length of 1/2" and slide it over the white and green wires now — before you forget and solder the thermistor to the wires — then trim and tin the leads of the thermistor to 1/4" long. Place a lead of the thermistor against the tinned white wire and heat the point of contact with a tinned soldering iron and solder the thermistor to the white wire.

Repeat this process with the green wire and the other lead of the thermistor. Again, slide the heat shrink over the solder thermistor leads and all wires and shrink them. Be sure to double-check your work.

With a DMM, you should measure the following resistances: base to ring — about 62K; base to tip — about 10K; and ring to tip — about 50K. The values vary, based on the temperature of the thermistor. Be sure to record the actual resistance between the ring and tip, as this is the actual resistance of the 50K resistor; this value is needed for the spreadsheet.

I have found that an easy way to label each temperature sensor is to print a small label and wrap it around the 3/32" jack housing. Then, cover the label with clear heat shrink. The heat shrink will protect the label and keep it from peeling off. After doing this (if you choose to), complete your remaining temperature sensors using the same steps.

Determining the Temperature Equation

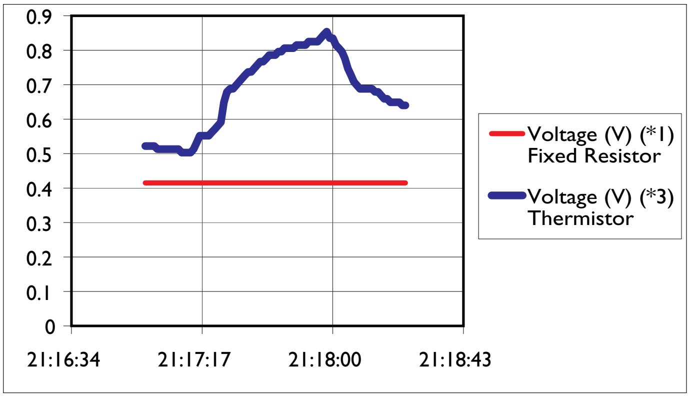


Figure 2. Graphed data from a cold, outdoor test.

This procedure is required for each temperature sensor, so repeat it for each one.

First, we'll need to start a spreadsheet. Create a new spreadsheet and enter the following labels: data and equations. Label the first column Temperature (C). In the column, enter the following temperatures:

-50, -45, -40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30

Label the second column Thermistor Resistance (k). In the column, enter the resistances listed below:

320.2, 247.5, 188.4, 144, 111.3, 86.4, 67.7, 53.4, 42.5, 33.9, 27.3, 22.1, 18.0, 14.7, 12.1, 10.0, 8.3

Be sure to line up the values so that –50° C is in the same row as 320.2 K. Note that I have rounded the resistances to only one decimal place.

Label the third column Temperature (F). Enter the following equation (I'm assuming you're using Excel and your data begins in row number two):

= ((+A2+40)*1.8)-40

Copy and paste this equation into the entire column. Label the fourth column Voltage (V) and enter the following equation:

= 2.5*(C3/(C3+51.1))

Note: The value 51.1 is the actual resistance of my 51K resistor. Change the equation to match your 51K resistor's actual resistance.

Copy and paste the equation in the entire column. As a sanity check, verify that the voltages are between 0.0 and 2.5 volts.

Now, we will create a chart of the temperature and voltage. First, click the Chart Wizard icon. Under Chart Type, select XY (Scatter); find Chart sub-type and select Scatter with data points connected by lines without markers. Click the NEXT button, then the Series tab. Click the REMOVE button until every series is removed from the Series window, then click the ADD button. Under X Values, select the Voltage column; under Y Values, select the Temperature (F) column, then click the NEXT button.

We don't need to label the chart, as we only want to find the equation describing the line, so click the FINISH button. Right click the line in the new chart and select Add Trendline. Now, click the Polynomial icon and enter 3 for the order. Under the Options tab, click Display Equation, then OKAY. You will notice that the trendline closely matches the original data series.

Write down the equation. It is needed to convert the voltages from the HOBO into temperatures. The equation should look something like this:

y = -24.196x3 + 99.972x2 – 195.64x + 141.23

Repeat this process on the remaining temperature sensors. Make sure to replace the fixed resistance in the Voltage column equation.

Now, you are ready to use your temperature sensor in a HOBO data logger. The cable is long enough that the HOBO can be left inside the warmer NS craft while the thermistor takes the brunt of the cold temperatures in NS. Before programming your HOBO, be sure your PC or laptop time is set accurately according to a GPS receiver. This makes data

processing more accurate later. (The HOBO time is set according to the clock on the PC it is programmed on.)

One possible complicating factor for the temperature sensor is that the fixed resistor may change values as it gets cold. To test for this possibility, I built a second voltage divider using just fixed resistors. (I used 10K and 51K resistors to simulate the temperature sensor.) The voltage divider was built following the same design for the temperature sensor, except that a fixed 10K resistor replaced the thermistor.

After connecting it and a real temperature sensor to a HOBO and launching a mission on the logger, I took the HOBO outside into the snow. I kept the 51K resistors in my hand and placed the thermistor and 10K resistor into a snow bank. After a few seconds, I brought the HOBO inside and did a read out of the data. The thermistor indicated the cold temperatures to which it was exposed, while the fixed resistor remained rock steady. Therefore, I concluded that the fixed 51K resistor left inside the NS craft will maintain a near constant resistance. If you are not lucky enough to live where it snows, a bowl of ice cubes will work just as well.

After recovery of the NS craft, read out the HOBO data and save the results into a text file. Start a spreadsheet and open the saved text file. Make sure the file is converted properly (with comma delimiters). (If you aren't sure how to do this, refer back to the "Near Space" column in the May, 2004 issue of *Nuts & Volts*.) The data from the HOBO will have columns for each channel used on the mission and the time.

The HOBO time must be converted into Mission Elapsed Time (MET) or altitude. The voltages must be converted into temperatures. The equation to convert HOBO voltages into temperatures was found when you assembled the temperature and will look something like this:

= -24.196*(B3^3)+99.972*(B3^2)-195.64*B3+141.23

Create a new column for each temperature sensor and enter the appropriate equation for each sensor. Now, process your data.

A question comes up when looking at thermistor data. How much does the resistance of a fixed resistor change as the temperature changes? If the fixed resistor is not truly fixed, then the results from the thermistor will be inaccurate. To address this issue, I created a second voltage divider. In this "temperature sensor," both resistors were fixed.

I placed one resistor (the test resistor) and the thermistor from the real sensor into a snow bank and left the other resistors in my hand. I recorded voltage readings for about 90 seconds. (It was cold outside!) During the second half of the measurements, I removed the test resistor and thermistor from the snow bank. After downloading the data from the HOBO, I graphed the results, which are displayed in Figure 2.

The resistance of the fixed resistor stayed constant throughout the experiment. As a result, I can conclude that temperature variations will not affect the fixed resistor in the temperature sensor. This implies that our results should be as accurate as the thermistor can provide.

Conclusion

Now, you've learned how to build temperature sensors for your HOBO data logger with external channels. The temperature sensing element is a thermistor — or temperature sensitive resistor. It is combined with a second fixed resistor in series to create a voltage divider. Power to operate the temperature sensor comes from the HOBO data logger, so no additional batteries are needed to record temperature.

The voltage drop across the thermistor is recorded by the HOBO and imported into a spreadsheet after recovery. The necessary equation to convert these voltage readings into temperatures was determined with a spreadsheet when the sensor was created. Any experiment requiring a temperature be recorded can use this temperature sensor.

Onwards and upwards,
Your Near Space Guide **NV**

Resource

HOBO data logger
Onset **www.onsetcomp.com**

The Latest in Networking and Wireless Technologies

Open Communication

Totally Wireless — ZigBee Is Making It Happen

We seem to be on a path leading to a totally wireless electronic lifestyle. The progress has been continual over the years, thanks to semiconductor technology and other advancements. More recently, there has been a flurry of announcements that make wireless everything possible. ZigBee is an important aspect of this.

It all probably started with wireless hobbies, like radio controlled models; that field still has a huge following today. Now, add robots to that. The TV remote control probably came next. Those early ultrasonic remotes were popular, but then we finally got the infrared (IR) versions of today that operate virtually every consumer electronic device we own. Garage door openers were another early wireless product.

Of course, don't forget cordless phones. Pagers were also popular, but less so now that cell phones are everywhere and are slowly replacing traditional, wired phones. We also have Bluetooth headsets on our cell phones and some PC peripherals, like printers. We also use Wi-Fi wireless LANs at hot spots in airports and hotels to get Emails on our laptops. We exchange digital photos and play games on our cell phones.

We have wireless networks on our PCs at home and at the office. Furthermore, most new cars now feature remote keyless entry on the door locks. So, the "cutting of the cord" continues. When the new, ultra wideband (UWB) chips become available soon, we will have cheap, wireless audio and video distribution throughout the house.

Many of you who follow the wireless trend probably already know about the many chips and modules available to make things wireless. These little radios operate in the unlicensed industrial-scientific-medical (ISM) Part 15 FCC (Federal Communications Commission) bands — like 315, 433, and 902-928 MHz. They use ASK or FSK modulation and transmit simple, serial data. Common uses are remote control and — in some cases — simple telemetry, like remote temperature monitoring.

Now there is another new technology that promises to make wireless ubiquitous, not only in the home, but also in the office, as well as the factory and plant. Known as ZigBee, this new wireless standard is putting wireless wherever you want it — at a very reasonable cost.

Figure 1A. The star network, where an FFD supervisor controls transmission between all nodes.

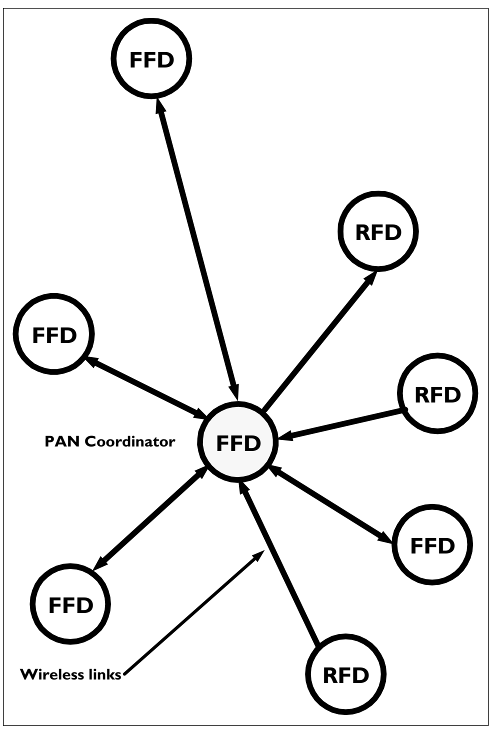
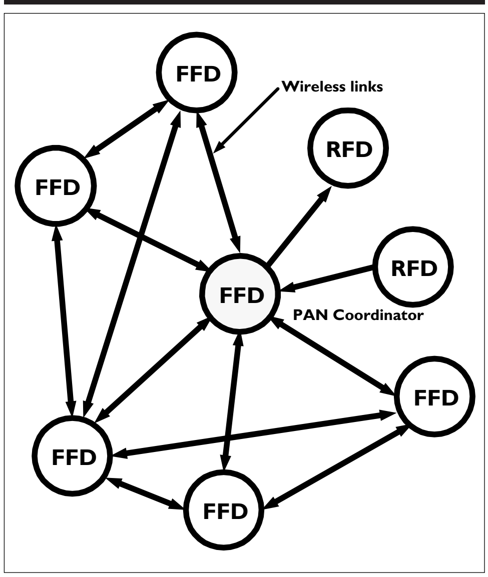


Figure 1B. The mesh or peer-to-peer network. FFD nodes can talk to all other FFD nodes if they are within range.



What on Earth Is ZigBee?

ZigBee is the trade name of the wireless technology standard that is primarily identified by its Institute of Electrical and Electronic Engineers (IEEE) designation 802.15.4. It is one of several personal area network (PAN) wireless architectures. Bluetooth is the main one and has been around for a few years. Bluetooth uses frequency hopping spread spectrum in the 2.4 GHz ISM band with a data rate up to 1 Mbps.

While Bluetooth has been adopted in a variety of applications, its use is limited because of its complexity and

cost. So far, its main application has been in wireless cell phone headsets. On the other end of the spectrum of wireless products are the cheap and simple wireless chips and modules; these are too limited. ZigBee fills that gap between the two with a low cost, as well as automatic networking capability, if needed.

ZigBee standard wireless equipment is specified to operate in three license-free ISM bands, including 868 MHz (Europe) and 915 MHz and 2.4 GHz in the US. Its goal is to provide reliable data transmission at modest speeds over a distance of up to about 10 meters. Longer ranges are possible, depending upon the environment and antenna type, size, and height.

There are 16 channels in the 2.4 GHz band, 10 channels in the 915 MHz band, and one in the 868 MHz band. The transmission is by packets 128-bytes long with a data payload that can be up to 104 bytes. The speed of transmission is 20 kbps in the 868 MHz band and 40 kbps in the 915 MHz band using direct sequence spread spectrum (DSSS) and BPSK modulation. The data rate is 250 kbps in the 2.4 GHz band using DSSS and offset-QPSK. A 16- or 64-bit address can be used to identify ZigBee transceiver nodes. Automatic error detection is built in.

You are probably thinking about how slow ZigBee is. Well, compared to other popular wireless LAN standards — like Wi-Fi — it is slow. With Wi-Fi, the base rate is 11 Mbps for 802.11b and up to 54 Mbps with 802.11a/g. The 802.15.3a UWB is even faster — about 110 Mbps. Those standards work great for LANs and high speed transport of video and audio. ZigBee is not designed for such service. It is intended for slow speed monitoring and control in the home and industrial environment. In some cases, even the 2.4 GHz 250 kbps ZigBee mode is overkill.

Automatic Ad Hoc Networks

The really big feature of ZigBee is its ability to automatically form ad hoc networks with nearby transceivers. Each transceiver contains a radio with a transmitter (TX), receiver (RX), and microcontroller. It is called a node in the network. The nodes constantly send out a beacon signal, then listen for a response. When a node gets near enough to another node, they automatically link up and talk to one another. The software used with the system defines how the two nodes exchange data.

ZigBee uses an access method known as carrier sense multiple access with collision avoidance (CSMA-CA). This technique allows multiple nodes to share a channel. If one transceiver is sending data, the others just listen and do not send until

that transmission is complete. Then another transceiver may send. If two or more transceivers try to send simultaneously, they both stop and wait a random length of time, then try again. This allows everyone a chance to send and/or receive with minimal interference.

Three network topologies may be used, including a star, mesh, or cluster tree. The star and mesh are the most common (see Figure 1). In the star, one of the nodes acts like a supervisor or coordinator and the others act as workers. All communicate by way of the supervisor. The mesh is also known as a peer-to-peer network. Here, any node can talk to any other node and data can be passed from one to another by a variety of paths. The cluster tree is just a more complex mix of the star and mesh, combined for larger applications.

In the networks, there are basically two types of ZigBee nodes — a reduced function device (RFD) and a full function device (FFD). The RFD is a simple, cheap node that may be send only, receive only, or a combination that just does some simple operation, like turn a light on or send a temperature reading every several minutes.

The RFD can look for other available nodes, as well as send and receive data. The FFD is more powerful and complex. It serves as a network coordinator. It manages links with RFDs or other FFDs. It handles all network traffic and routing. RFDs can only talk to FFDs, but FFDs can talk to any other node.

One of the major features of the mesh network is its ability to extend the range of remote nodes. If a node needs to communicate with its network coordinator — but is too far away — it can transmit to another nearby node, link up, then have other, intermediate nodes forward the data to the supervisor. The data may pass through several other nodes serving as radio relay links along the way.

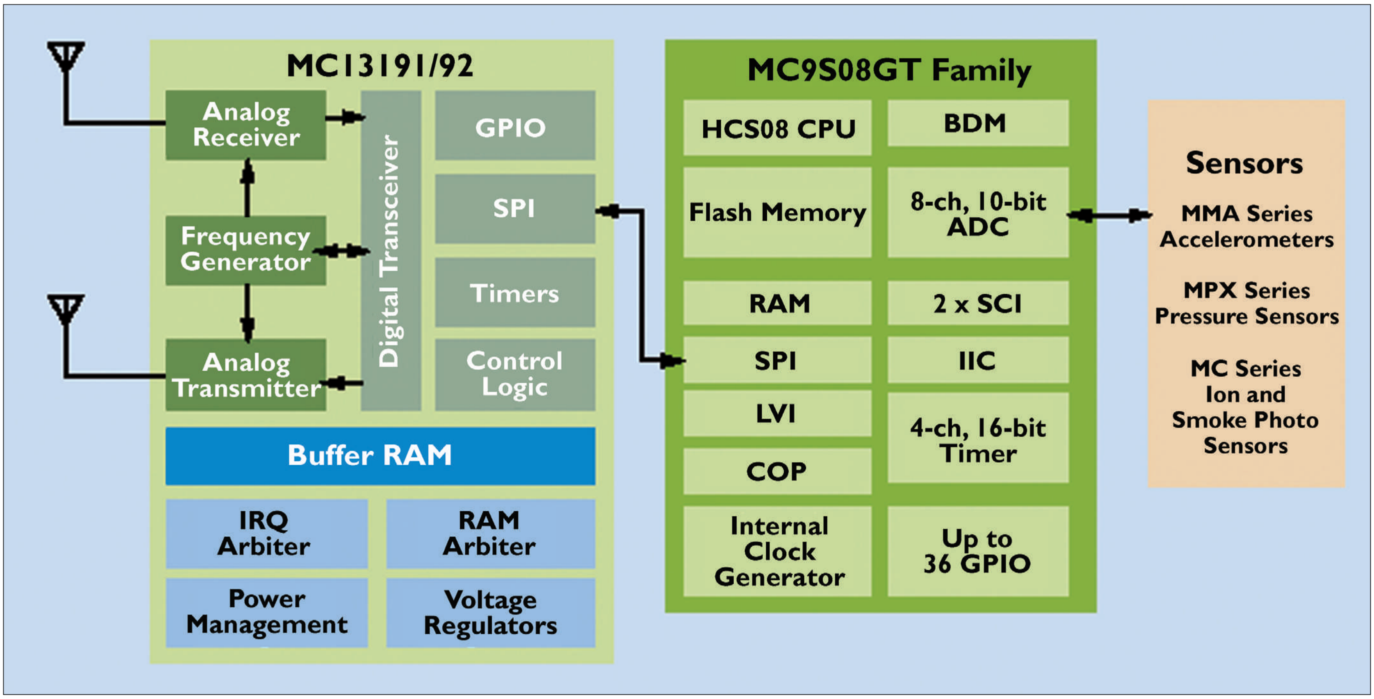
Another big feature of ZigBee is its extremely low power consumption. Even when transmitting, the power is very low — in the 1 mW range. If the transceiver is not being used, it goes into a sleep mode, where the power consumption is microwatts, at most. If a signal comes in, the chip wakes up and sends or receives, as called for by the application.

With such low power consumption, a remote node can be battery-powered and have a life of up to many years before a new battery is needed. This is a truly great benefit, as it makes possible a whole new range of heretofore unsuitable applications in monitoring and control.

ZigBee Apps

The neat thing about ZigBee is that it is a fully defined standard with commercial chips and modules available to fit into any applications where wireless is wanted. You don't have to be a wireless wiz and a black art RF designer to build wireless into any other product. It is all pretty much done for you. All the protocols are fully defined and all ZigBee-based products are compatible with one another.

Figure 2. Block diagram of the Freescale Semiconductor ZigBee components. The MC13191/192 is the single chip RF transceiver. It interfaces via a fast serial interface called the SPI. The upper layers of the ZigBee software are implemented in the MC9S08GT embedded controller with its various memories and interfaces. The sensors in this case are Freescale accelerometers. Courtesy Freescale Semiconductor (Motorola subsidiary).



While the IEEE 802.15.4 standard defines the protocol, that often does not guarantee that all ZigBee devices will talk to one another. The job of interoperability falls to the ZigBee Alliance. This is an organization of about 70 major vendors of ZigBee chips, boards, or products who have banded together to define interoperability tests and procedures that ensure that ZigBee devices are fully compatible. The ZigBee Alliance is an industry association like the Wi-Fi Alliance that promotes the 802.11 wireless LAN standard and tests products to make sure they all work together.

ZigBee is targeted at applications that involve a low data rate, short range, and simple functions. Home automation is one key area. Another is commercial and industrial monitoring and control. In the home area, ZigBee is ideal for the remote control of lights, ceiling fans, drapes, heating and air conditioning systems, security systems, sprinklers, and even appliances.

Because it is small, cheap, and low power, it can be used in just about anything. It can also monitor and report the status of smoke detectors and remote temperature sensors; it could even be a part of an automatic utilities meter reading system. ZigBee may even replace IR remote controls in consumer gear and may become the way that players use the controllers on their video games. Toys will also use ZigBee. It's that cheap and easy on batteries.

In the commercial market, think of ZigBee as a wireless system that allows building managers to monitor and control all lights remotely or operate heating and air conditioning systems more efficiently by monitoring and controlling each building sector separately. It can turn the system off and on, in addition to being able to open, close, and modulate the air vents. It can also monitor smoke and carbon dioxide detectors and even implement occupancy or proximity sensors.

While all of that has been technically possible for years, the cost has been prohibitive because of radio and battery costs, not to mention maintenance issues. Now — with the super low cost and miniscule power consumption — wireless everything has become practical and affordable.

In industry, ZigBee is ideal for the big chemical plants or factories. Remote sensors can be placed where needed and their signals can be sent wirelessly to a central monitoring station. Such telemetry can provide details on all aspects of a process or manufacturing method without adding expensive wiring. Installing a wire may not seem like a big deal, but — in an industrial setting — it costs big bucks to wire up a sensor because a licensed electrician or union technician must do it at huge cost, in addition to the price of cable, conduit, and accessories. Wireless is dirt cheap in comparison.

Remote control is also possible. As the result of feedback from flow, temperature, or pressure sensors, control computers can issue commands to turn on or off pumps, fans, conveyers, or other equipment, as needed. Even the auto makers are making their assembly lines more automatic by adding inexpensive wireless monitors and controls, as well as assembly robots.

The Hardware and Software of ZigBee

Figure 2 shows a simplified block diagram of a ZigBee product. This is Freescale's (formerly Motorola Semiconductor) new MC13191/192 family of transceivers. It has two basic parts — the radio IC and an embedded controller, like Freescale's (Motorola's) HCS08 MPUs. The radio is the transceiver that implements the 802.15.4 IEEE standard. This is usually a single chip device. The standard is further implemented with software that runs on the microcontroller.

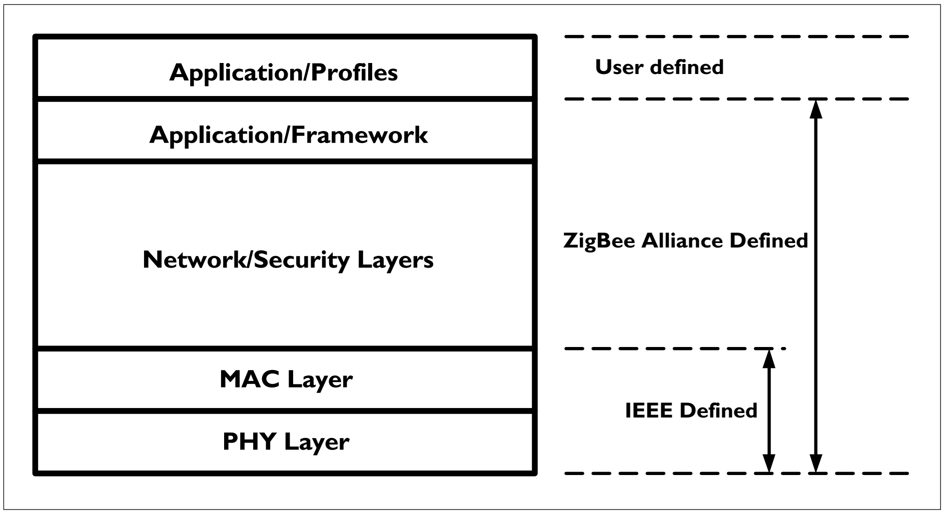
Figure 3 shows a diagram of the various layers of hardware or software that make up any data communications system. The lower two layers are known as the physical layer (PHY) and the media access controller (MAC). These are usually implemented in hardware in the ZigBee chip. The remainder of the layers are software and are often referred to as the stack.

Useful Websites

Institute of Electrical and Electronic Engineers
www.ieee802.org/15/pub/TG4.html

ZigBee Alliance
www.zigbee.org

Figure 3. The ZigBee layers. All data communications systems and protocols use a layered format with data flowing up (receive) or down (transmit) through the layers. Layers are usually software, except for the PHY and MAC layers, which are implemented in hardware. The IEEE standard defines these lower layers only. The ZigBee Alliance defines the other layers, except the top layer, which the designer defines for the specific application.



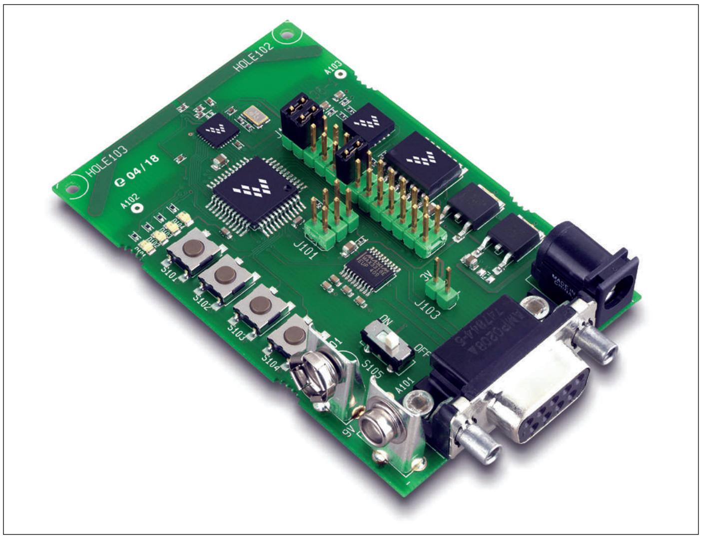


Figure 4. The Freescale Semiconductor 13192DSK-A00 developer's starter kit for developing ZigBee applications with the MC13191/192 chip set. Available from Metrowerks. Courtesy Freescale Semiconductor (Motorola subsidiary).

That is where the embedded microcontroller comes in. The ZigBee Alliance defines the software for things like networking functions, as well as security. The way to visualize the stack is that, during a transmit operation, data at the upper layer in the application is passed down through the lower layers, picking up security and, eventually, getting formatted into packets in the MAC layer — with the PHY layer actually doing the transmitting.

In the receive mode, the radio data in packet form comes into the receiver PHY layer and is passed up to the MAC hardware for disassembly before being passed on up through the various layers, until the needed data is used by the application at the top layer.

A node may send data without security or protection if the application is not critical. Two levels of security are available as options. The first is to use what is called an access control list (ACL). The supervision node knows of the other valid nodes and only accepts data from or sends data to those nodes on the ACL. Security via encryption uses the NIST's 128-bit Advanced Encryption Standard (AES).

The ZigBee Alliance also provides certain software for specific types of monitoring and control functions. If you can use the standard functions, fine. If not, you will need to write the software that handles your specific application. The upper layers in Figure 3 are the specific application code.

Most ZigBee projects tend to be software projects. Very little is needed in the radio design. The most critical part is a good antenna, which is the make or break success factor in any wireless application.

Most semiconductor manufacturers who make chips for this market also have a devselopment package consisting of a couple transceivers and a hardware platform that allows you to build your own system (see Figure 4). This is the Developer's Starter Kit for the new Freescale chips mentioned earlier (available from Metrowerks). A major part of this is a software development system that lets you create the code to do what you want. Typically, libraries of precoded applications are available from the manufacturer or the ZigBee Alliance.

ZigBee is still relatively new, so few products are available yet, but, as new chips, modules, and development boards come on the market, you can expect to see lots of ZigBee-based products — or not. Since wireless will be built in, you won't even see it. Of course, we will probably take if for granted, like we do most other electronics products, but isn't that the way we are and the way we like it?

Until next time ... **NV**

Resources

Atmel Corporation
www.atmel.com/ad/wireless

Chipcon AS
www.chipcon.com

CompXs
www.compxs.com

Freescale Semiconductor
(Formerly Motorola's Semiconductor Products Sector which was spun off recently and is a wholly owned subsidiary of Motorola.)
www.motorola.com/zigbee

Microchip Technology
www.microchip.com/nanowatt

ZMD
www.zmd.biz

CLASSIFIEDS

CLASSIFIED ADVERTISING

$50.00 Per Inch — No extra charge for color *(Limited time offer).*
Classified ads must be paid in full prior to the closing date. Visa/MC/Amex accepted. Payment for ads received after the closing date will cause the ad to be placed in the following issue, at our discretion. Minimum charge is one inch with half-inch increments.

No proofs will be sent. Ads to be typeset by *Nuts & Volts* must be received by the closing date. Supplied ads must be received by the artwork due date.
Call the office at 951-371-8497 or Email classads@nutsvolts.com for closing dates, available sizes, and special prepay discount offers.

Components

RF PARTS™ CO.
From Milliwatts to Kilowatts℠
Tubes, Transistors, Power Components.
Email: rfp@rfparts.com • Web: www.rfparts.com
800-737-2787 Fax 888-744-1943

FREE 120 Pg CATALOG
Electronic components, kits, test equipment, tools, and supplies for hams, hobbyists, and businesses. Many hard-to-find items like variable capacitors, vernier dials, coil forms, magnet wire, and toroids.
Ocean State Electronics
www.oselectronics.com

RF Transistors, Door Knob Caps, Power Supplies, Tubes, Coax, Teflon Wire
2SC2879 2SC2290 3-500Z 4CX250B
See our website for other products
www.westgateparts.com
Westgate 1-800-213-4563

Subscribe today!
www.nutsvolts.com

Education

Command-Line Compilers start at $125
Windows IDE Compilers start at $350
Introducing the NEW MACH X Programmer
- Supports PIC12, PIC14, PIC16, PIC18 and dsPIC
- Reads HEX, COD, COF, and BIN files
- USB interface--No separate power supply required
- User selectable verify voltages (2V to 5.5V)
- Programs DIP chips with ZIF socket on unit and supports ICSP
- Start/Repeat push-button on unit for easy volume programming
- Can be used as an ICD debugger with the CCS Windows IDE Compiler

Only $149 with compiler and $199 without compiler

*Check out our new Hardware and Software Development Kits on the web at www.ccsinfo.com/hardware.shtml
CCS
262-797-0455
www.ccsinfo.com/picc
PIC® and PICmicro® are registered trademarks of Microchip Technologies Inc., in the USA and in other countries.

Affordable Robotics Training Courses in:
Basic Electronics
Digital Electronics
Relay Control
Servo Controllers
PLC Systems
Hydraulic Systems
From Basic to Advanced!
WWW.UCANDO-CORP.COM
1-800-678-6113
FREE SHIPPING!
UCANDO VCR Educational Products Co.
(Est. 1988)

Printer Supplies

Hard-to-find Printer Ribbons
INKJET REFILLS
INKJET CARTRIDGES
AT DISCOUNT PRICES
Write for price list or check out our web page.
H.T. Orr - Computer Supplies
249 Juanita Way
Placentia, CA 92870-2216
TOLL FREE 1-800-377-2023
LOCAL 714-528-9822
FAX 714-993-6216
email: Htorr@aol.com
http://users.adelphia.net/~htorr

Miscellaneous Electronics For Sale

MAKE SUPER STRONG 3D PARTS FAST
SHAPELOCK PLASTIC™
RAPIDLY CREATE PROTOTYPES, PARTS, SCULPTURES, BRACKETS, HOUSINGS, MOLDS
AMAZING PLASTIC MELTS IN HOT WATER, LOCKS RIGIDLY AT ROOM TEMPERATURE
INCREDIBLY TOUGH, LIGHTWEIGHT, MACHINEABLE, PAINTABLE, INEXPENSIVE
SHAPE BY HAND AND RESHAPE REPEATEDLY **WWW.SHAPELOCK.COM**

RS485/422/232/TTL
ASC24T $45
- Converters
- Repeaters
- Fiber Optics
- Digital I/O
- Multidrop RS232
- Custom Units
- Auto TX Enable

Extensive Interface Product Line
RS232 "Extension Cords"
Up to 115.2 Kbps, 4000 ft. ++
Large Multidrop Networks.
Isolated Units. Smart Units
Remote Relay "Extension Cords"
Call the RS485 Wizards at
(513) 874-4796
RES R.E. Smith
www.rs485.com

OVER 4,300 ITEMS IN STOCK
Surplus & Refurbished Electronic Equipment Parts & Accessories
Audio, Communication, Computer, Telephone, & Video Equipment. Repair Parts & Service Manuals.
SMC ELECTRONICS
www.smcelectronics.com
On Sale Now
Cordless Telephone Battery Packs
50 - 75% OFF RETAIL PRICES!

Call us TODAY to start your subscription to *Nuts & Volts!*
800-783-4624

Computer Hardware Wanted

DEC EQUIPMENT WANTED!!!
Digital Equipment Corp. and compatibles.
Buy - Sell - Trade
CALL KEYWAYS 937-847-2300
or email buyer@keyways.com

Security

www.matco.com
Miniature CMOS Camera
CML-100/CMP-101
1/4" CMOS, 380 TVL,
3 Lux/f2.0, 3.6/5.5mm Lens
B/W: $29/ea Color: $39/ea
Color Mini Pinhole Camera
BX-123LC/PC
SONY 1/3" CCD,
380 TVL, 0.1 Lux/f2.0,
3.6 mm Lens
Size: 0.9" X 0.9" X 0.5"
$69/ea *(with Audio)*
Super Hi-Res Color Lens Box Camera
BX-130LC-HR
SONY 1/3" CCD,
470 TVL,
0.4 Lux/f2.0,
3.6 mm Lens
$189/ea
(800)719-9605 sales@matco.com

consumertronics.net
Hi-Tech Survival Offers!
Electronics, security, energy, computers, Net, phones, medical, legal, financial, weird. **Cat.$1**

www.matco.com
Color Super HAD CCD Camera
SX-920-C-SH
$89/ea
1/3" Super HAD CCD Sensor; Digital video processor; 380 TV Lines; 0.2 Lux/f1.4; Supports Auto Iris lens for both DC drive & video drive; AES, AGC, AWB, BLC; Lens and bracket not included.
(800)719-9605 sales@matco.com

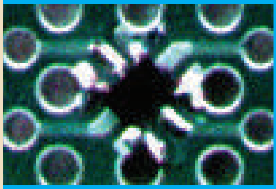
Surveillance
Counter-spy Equipment
Security Cameras
Telephone Recorders
Online Catalog Only
www.MJelectronics.com
Tel: 914-699-2294

Join our
ONLINE
electronics forums!
www.nutsvolts.com

CLASSIFIEDS

Design/Engineering Services

OK, so now we have the world's smallest Microprocessor in SOT 23-6 pin, smallest Op Amp in SOT 23-5 pin, smallest Power FET in SOT 23-4 pin. But, how do you work with them without spending an arm and a leg??? ONE PASSircuit™ !



www.onepasinc.com

Your Idea on a budget

Product Development · Electrical Design · Firmware · Far East Manufacturing · Prototyping

www.elementinc.com 303-466-2750

Schematic Capture and PCB Layout

Hardware, Firmware and Software Design

Can Do any Size Schematic and Layout, Up to 48 Layers
* 1 or 2 Component Sides
* SMT and Thru-Hole
* Full CAMs, PCB Prototyping

All Development and Design done by B.Eng.
* Analog and Digital
* PIC Firmware with C

613-521-5591

Reasonable Rates MikeT@zetaware.ca

www.zetaware.ca

Electronic Engineering Consulting

Product development from concept to completed circuit board or product. Digital and analog expertise. Microcontroller design for Motorola, Intel, TI ultra low power Microcontrollers, In-House schematic capture and PCB layouts.

Dave Lancaster
Infotech Controls
P.O. Box 2822
Lower Burrell, PA 15068
or call (724) 337-8865
Infotechcontrols@comcast.net

* Circuit board layouts
* Prototype assemblies

WWW.OSPREYELECTRONICS.COM

Convert your sketch or print into a quality pcb for a reasonable price. Visit us on the web or call Osprey Electronics at (208) 665 1688 (USA)

Misc. Electronics Wanted

Wanted: Balancing machines & vibration analyzing equipment manufactured by the following: •Spectral Dynamics •Hofmann •Bentley Nevada •Schenck •IRD Mechanalysis •Gishott
Contact Mike Park at E.T. Balancing, 12823 Athens Way, Los Angeles, CA 90061
310-538-9738
FAX: 310-538-8273

Amateur Radio

ZAP CHECKER MODEL 270

WIRELESS INSTALLATION METER

WITH LOG PERIODIC 1.8 - 4.5 GHz Ant.

for WIFI, WLANs & SURVEILLANCE

- Aims and Aligns Antennas
- Tests Transmitter/Antenna Output
- Measures Baseline RF and RFI
- Identifies HOT and COLD spots
- Finds Hacker Sites & Cable Leaks
- Optimizes Hub Placement

$329 w/ directional 1.8 - 4.5 GHz Ant. (+ $7 S&H, CA Residents add 8.25% tax)

ALAN BROADBAND CO.
93 ARCH ST., REDWOOD CITY, CA 94062
TEL: (650) 369-9627 FAX: (650) 369-3788

WWW.ZAPCHECKER.COM

PROFESSIONAL EAVESDROPPING DETECTOR

2.4 GHz BUGS detected at 100 + feet

ZAP CHECKER MODEL 270 with 2.4 GHz YAGI ANTENNA

$549

- DETERMINES DIRECTION
- SUPER FAR-FIELD DETECTION
- HOMES-IN & PINPOINTS LOCATION
- 10 MHz - 4.5 GHz BANDWIDTH, - 70 dBm at 2.4 GHz

ALAN BROADBAND CO.
(650) 369-9627 (888) 369-9627 FAX: (650) 369-3788

WWW.ZAPCHECKER.COM

Speakers

PARTS EXPRESS
YOUR ELECTRONICS CONNECTION

The Audiophile Source

- Speakers
- Electronics
- Connectors
- A/V Accessories

Call for a Free Catalog
1-800-338-0537
or visit us at
parts-express.com

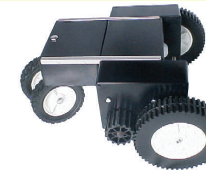
SOUCE CODE: NVM2

Robotics

canbotics.com

Autonomous robots
Panning proximity sensors
Motherboards • Motor Drivers

Attention Resellers!



As low as $99

Build robots for profit.
Get parts lists, suppliers, & manual with color photos.
Several models available.

www.kadtronix.com

MUSCLE WIRES®

NASA/JPL

Sojourner MAE Instrument operated by 3 cm of Flexinol 150 LT Muscle Wire

Discover the Future!

Discover **Muscle Wires** Motorless Motion

They actually shorten in length when powered and lift thousands of times their own weight!

• Strong • Silent • Low Voltage • 11 sizes •

Project Book & Deluxe Kit (#3-168) just $59.95

Muscle-Wires.com • Mondo-tronics, Inc.

Order Toll Free 800-374-5764

ROBOTIC CONTROLLERS

Robot Bases. PIC, OOPic, Stamp and multi-servo controllers. Also, Pocket TestBench. Chips, kits, and assembled.

www.oricomtech.com

Printed Circuit Boards

Printed Circuit Boards

Prototype & Production
Prototype 2 Layer As Low As
$12 Each
Prototype 4 Layer As Low As
$30 Each
includes (up to 20 sq. in. ea.) tooling plot, L.P.I. mask & Silk

www.pcbexpress.us

Production: 2 Layer
As Low As $0.07 Sq. in.
Production: 4 Layer
As Low As $0.15 Sq. in.

PCB Express, Inc.
Phone: (847) 952-8896
Fax: (847) 952-8893
E-Mail: pcbexpress@aol.com

Audio/Video

www.matco.com
4 Channel Digital Video Recorder
DVR-2200
$299/ea

Recording rate: 30 fps full size/240 fps quad size; Up to 250 GB optional removable HDD; Wavelet compression format; Alarm input/output; Video loss detection; Multiple quick search; POP/PIP; RS-232, RS485 Communication protocol.

(800)719-9605 sales@matco.com

ALC252 miniature speech processor module $27.95

C&S Electronics
www.candselect.com
203-261-5388

www.matco.com
4 Channel PC Based
Digital Video Capture Card
DVRC-XP4
New Low Price
$139/ea

30 fps, 640 x 480, RCA Video Input, 1 Channel Audio Input

(800)719-9605 sales@matco.com

VIEW MASTER PLUS
125 CH. UNIVERSAL
CABLE CONVERTER

ORIGINAL EQUIPMENT
SCIENTIFIC ATLANTA
JERROLD & PIONEER
GENERAL INSTRUMENT

1-888-777-9123
1-888-675-3687

www.matco.com
Pocket Digital Video Recorder

Built-in 20GB H/D for 40 hrs real-time recording in MP4, A/V input/output, USB 2.0 interface, built-in 3.5" LCD color monitor, 5-1/8" x 3-3/8" x 13/8", Weight 0.67 Lb.

$660/kit

(800)719-9605 sales@matco.com

News Bytes

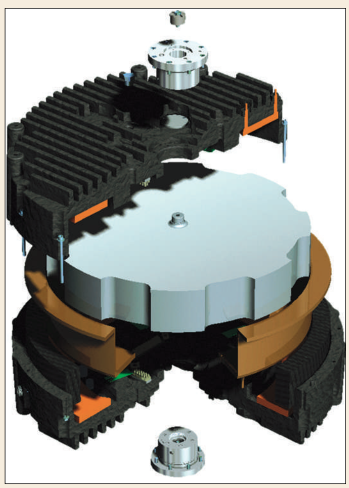
(continued from page 40)

constructs, while executing at increased low level language performance. Included with the development tool set is a code profiler that helps identify frequently executed code sequences, i.e., those areas ripe for optimization.

The Stretch S5 engine incorporates the widely accepted Tensilica® Xtensa® RISC processor core. A graphical IDE is available for about $900.00 and versions of the S5000 line run between $35.00 and $100.00 each (manufacturer quantities), depending on capability. Visit **www.stretchinc.com** for more information.

Battery-Free Power

You might be asking, "Just what is wrong with batteries?" Well, the simple fact is that they have some serious drawbacks — limited life, temperature constraints, disposal problems, and the like. A new solution from Active Power of Austin, TX deals directly with these issues in a novel way. Their CleanSource® UPS systems are based on flywheel technology — that's storing energy in a high speed rotating mass. Available in four models — from 65 kVA to 130 kVA — they sport a peak efficiency over 95% and are designed to power critical loads until a standby generator can take over.



The CleanSource units combine rugged steel flywheels with advanced power control electronics in a constantly spinning, quiet, low friction system. They feature low input harmonic distortion and outstanding overload capacity, along with the ability to recharge in about two and a half minutes (seven and a half from a cold start).

For all the energy they store, physically they aren't that large — 34" x 59" x 78." As an option, they offer OSHPD pre-approved seismic Zone-4 anchoring capability.

In English, this means you can really bolt them to the building, so an earthquake doesn't cause a two ton flywheel to jump all around your power distribution room. For more product and technical information, visit **www.activepower.com**

Advanced Techniques for Design Engineers

The Design Cycle

Generating Random Numbers in Code

Think of a number between 0 and 10. Is your number 3? Did I guess right? If I guessed right, would you say that your mind generated a random number and I just happened to be lucky enough to guess what it was? Or, do you have an affinity to the number 3? Do you have three kids? How about three cars? Why did you come up with the number 3? If I missed the guess and your number was something other than 3, how did you come up with that particular number? Was your choice of numbers really random?

Believe it or not, your numerical choice of numbers was most likely not at all truly random. The first thing I did to kill the truly random number selection process was to place a boundary on your choices (0 to 10). The best you could have done toward producing a random number was to provide a quasi-random set of numbers by rearranging the positions of the numbers inside the 0 to 10 number set.

Random Numbers

True randomness is only exhibited in nature. Let's get really deep for a moment. Imagine that you are a dandelion seed and a sudden burst of wind arrives and puts you into flight. Do you have any idea where you will land? You may have been "programmed" to expect wind, but you have no control over when enough wind will arrive to carry you away. Do you have any control over where you will land? If you were a dandelion seed and you could talk, the answer would be a resounding no for each of the previous questions. Your fate as a dandelion seed is determined entirely by nature and is, therefore, truly random.

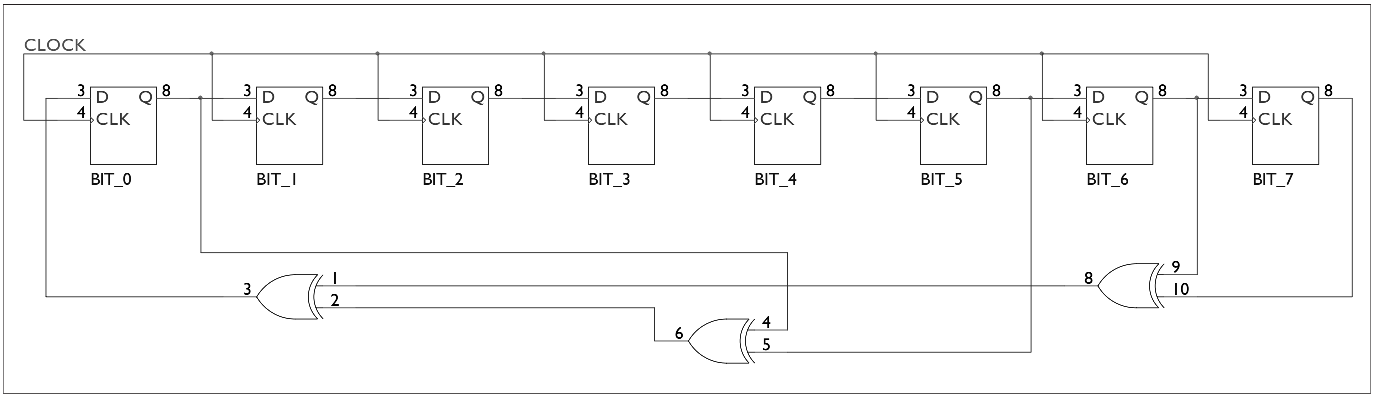
You as a human are also part of nature. Given enough time (all of your life), paper, pencils, and food (in infinite quantities), you could probably become a really good random number generator. The problem is that you wouldn't be able to generate random numbers fast enough to keep up with that mainframe that is trying to calculate where a certain atomic particle may take up residence next.

Now that you're off the hook as the perfect random number generator, don't depend on that mainframe to come up with the perfect random sequence of numbers. If it did, there would be two things wrong. First, the mainframe would be a living and thinking entity, totally attached to nature, just as you are. Second, the stupid thing would be broken. Since the mainframe — or any other computing device for that matter — cannot be alive and be broken at the same time, you can forget about the truly random number generator in the guise of a computing machine.

There's one more reason why you will never see a perfect sequence of random numbers generated by a computer: programming. Computers can only do what you instruct them to do and nothing more. Let's bring that down a few levels to a microcontroller.

The UPS delivery person brings

Figure 1. A simple eight-bit shift register. We're not going to build this up in the traditional way.



you a tube of PICs. You merrily accept the delivery and randomly take one of the PICs out of the anti-static tube to use in a circuit you're working on. In a perfect world, you would simply plug the PIC into your circuit and apply power. After all, the PIC is intelligent enough to know what you want it to do, right? Not here on Earth — at least not yet, anyway. You must write instructions that the PIC can understand to allow it to participate in your circuit and provide the results that you expect.

Pseudo-Random Numbers

That brings us to another way of saying "random number" — pseudo-random number. If you've played any of those "memory" games, you've done the pseudo-random number thing. Pseudo-random numbers appear to be random, but are really repeating patterns of numbers. That mainframe is powerful enough to string out enough numbers to make it seem that the numerical string of numbers is truly random. However, somewhere out there in numerical space, the mainframe will run out of computing space and start counting all over again using the same numbers as before. That may take a very, very long time, but be assured that it will happen.

Remember, that big piece of computing iron cannot be thinking for itself and reside in our picture of reality. That mainframe computer relies on the same math you were doing with the pencil and paper in your last life as a human random number generator.

So, are pseudo-random numbers the best that we can get? Unless you know the real story behind Area 51, that's about as good as it gets, if you depend on our current understanding of mathematics and a computing machine. However, we can use our understanding of the technology behind nature to actually approach producing really good natural random number strings. Like the wind that provided lift for our dandelion seed, noise can be utilized to get some pretty good random number sequences.

Avalanching a common transistor junction is one way of generating random noise. The noise is then fed into a digital shaping circuit to allow a computing machine to "randomly" select parts of the resulting digital waveforms for use in generating a sequence of random numbers. If you're not averse to glowing the dark, the response of a Geiger counter to radiation is another way nature puts randomness into your world. You can even get random numbers from various "natural" devices via some sites on the Internet.

If you're a scientist, you probably have access to a mainframe or a series of paralleled RISC (Reduced Instruction Set Computer) machines that can really churn out the MIPS (Million Instructions Per Second) and generate some decent random (actually pseudo-random) numbers. On the other hand, if you aren't out in the garage trying to displace atomic particles or invent a warp drive, you most likely have access to something that can generate smaller strings of random (actually pseudo-random) numbers just as well ... a microcontroller.

A Linear Feedback Shift Register

Consider Figure 1. You could rummage through your parts bin and come up with the necessary ICs to build this circuit, but laying out a point-to-point design and soldering in all of the discrete components is hard work. Plus, you'd have to come up

Figure 2. The same idea that is conveyed in Figure 1 is depicted here logically. All we have to do is figure out how to write some code to represent it.

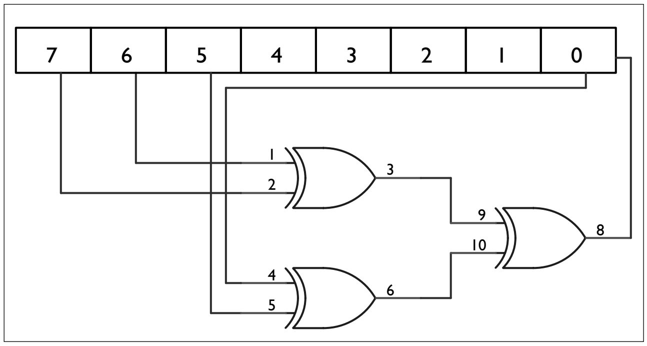


Table 1. There will always be an even number of tap sets associated with an LFSR.

Eight stages, four taps: (six sets)
[8, 7, 6, 1]
[8, 7, 5, 3]
[8, 7, 3, 2]
[8, 6, 5, 4]
[8, 6, 5, 3]
[8, 6, 5, 2]

Listing 1. Here's a software implementation of Figure 2.

```
#include <16f877.h>
#include <f877.h>
#device ICD=TRUE
#device *=16

#fuses DEBUG,HS,NOWDT,NOPROTECT,NOBROWNOUT,NOLVP,NOWRT
#use delay(clock=20000000)
#use rs232(baud=57600,xmit=PIN_C6, rcv=PIN_C7)
#id 0x0401

int8 shift_reg_data,result,shift_reg[1];

#bit tap7 = shift_reg_data.7
#bit tap6 = shift_reg_data.6
#bit tap5 = shift_reg_data.5
#bit tap4 = shift_reg_data.4
#bit tap3 = shift_reg_data.3
#bit tap2 = shift_reg_data.2
#bit tap1 = shift_reg_data.1
#bit tap0 = shift_reg_data.0

#bit accum7 = result.7
#bit accum6 = result.6
#bit accum5 = result.5
#bit accum4 = result.4
#bit accum3 = result.3
#bit accum2 = result.2
#bit accum1 = result.1
#bit accum0 = result.0

void main()
{

        shift_reg[0] = 0x00;
        shift_reg_data = 0x00;
        result = 0;
        shift_left(shift_reg,1,1);
        while(1)
        {

                accum0 = tap7 ^ tap6;
                accum1 = tap5 ^ tap0;
                accum7 = accum0 ^ accum1;

                shift_left(shift_reg,1,accum7);
                shift_reg_data = shift_reg_data[0];
                 printf("%X ",shift_reg[0]);
        }

}
```

with a suitable clock circuit to push the bits through the shift register electronics. Alternately, you can do this with a minimal set of hardware components and implement the D flip-flop and XOR logic in code. The shift register flip-flops can be realized as an unused internal eight-bit SRAM register of a PIC. The three exclusive OR gates do not exist physically and can also be realized in firmware.

The pseudo-circuit you see in Figure 2 is a conception of the Figure 1 hardware as it would be implemented in firmware. The actual hardware in Figure 1 and the resultant firmware in Figure 2 are called Linear Feedback Shift Registers or LFSRs. An LFSR is actually a counter that produces pseudo-random bit sequences. Note that, in Figure 1, the outputs of some of the flip-flops are connected to inputs of the XOR gates. These connections are called taps. The XOR gates perform modulo-2 arithmetic, which is defined as:

$$0 + 0 = 0$$
$$0 + 1 = 1$$
$$1 + 1 = 0$$

The binary-weighted modulo-2 sum of the taps is fed back into the input of the LFSR.

Our LFSR is eight bits in length. In LFSR speak, that means that the LFSR has eight stages and can resolve 2^m-1 states, where m is equal to the number of stages in the LFSR. These states are called linear recursive sequences. The length of a linear recursive sequence is defined as the number of distinct numerical iterations that can occur before the sequence repeats itself.

If we choose the tap locations correctly and initialize the LFSR with the right value, our LFSR can produce 2^8-1 — or 255 — distinct states before the sequence repeats itself. When we place the taps in the right places and initialize the LFSR with the correct value, all of the possible combinations within the LFSR can be realized. This full realization of all of the possible numerical combinations is called a maximal length sequence. If you're wondering what that 256th state is, it's all 0s. A pseudo-random number of 0 is not very useful in most instances.

Some LFSR Code

As you've already figured out, the trick to getting as many pseudo-random numbers from an LFSR depends partially on where you place the taps. There is lots of polynomial-based math behind determining tap points. However, it's easier to use a tap table, like the one shown in Table 1. I've written a little bit of code to go with our LFSR tap table. Let's examine the LFSR code you see in Listing 1.

I could have just as easily written this in assembler. However, that wouldn't be fair to those of you that don't want to use a PIC. So, I opted for the universal language of C. As you can see in the #include area of the code, I did use a PIC and a Microchip MPLAB ICD 2 to debug and check my work. For those of you who want to duplicate the hardware I used, you can get what you need from Schematic 1 or you can use the same circuitry that I used to implement the digital filter.

The actual shift register is implemented as a byte-wide array called shift_reg. The shift_reg array byte will be fed from the least significant bit of the shift_reg array byte. We must have an easy way to implement the tap modulo-2 process without

having to shift bits around in the actual shift_reg byte. So, I defined another byte called shift_reg_data, which will mirror the contents of the actual shift_reg byte. All of the XOR modulo-2 stuff will be performed against bits (taps) defined inside of the shift_reg_data byte. The intermediate results of the XORing of the taps will be kept in the result byte, which is sliced up into eight, one-bit accumulators (accum0-accum7).

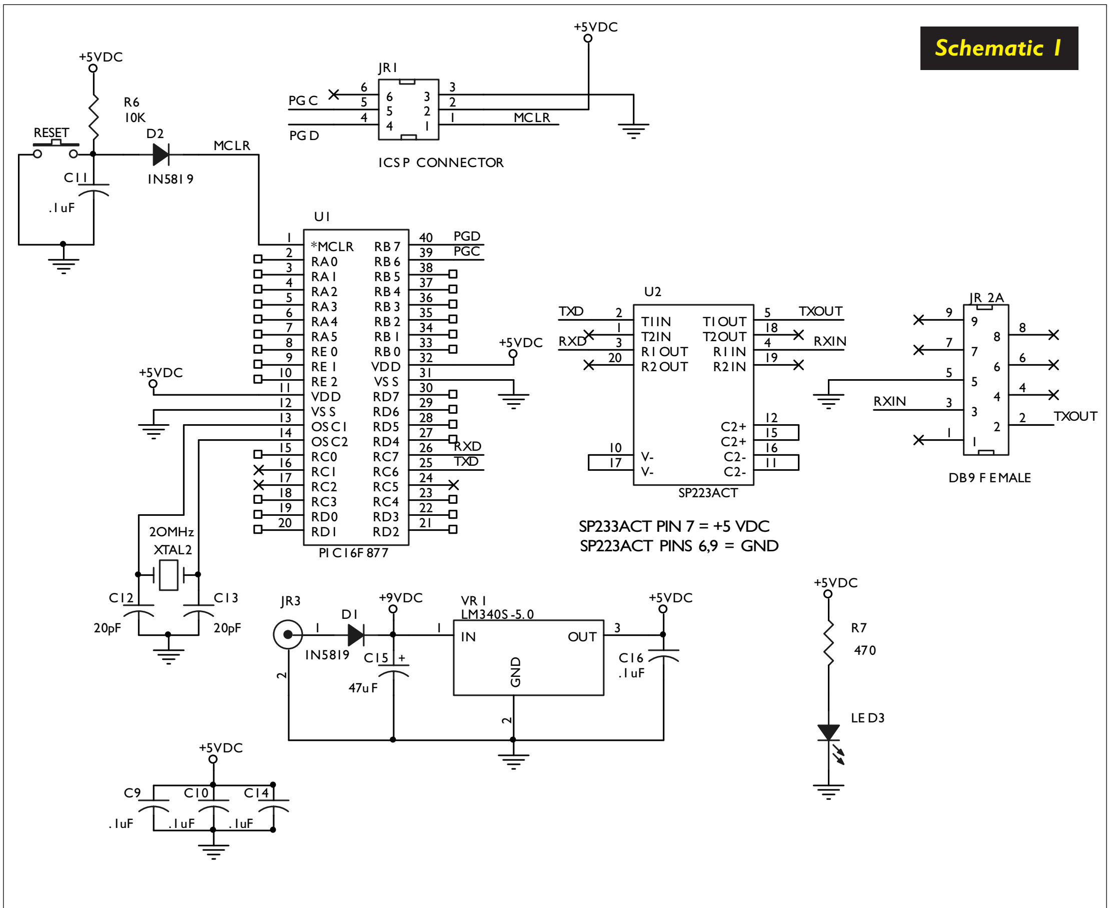
The first three C statements in the main() module simply clear the shift register, the shift register data mirror byte, and the accumulator byte. The shift_left(shift_reg,1,1) statement shifts a 1 into the low-order byte of the shift_reg array. The 1 immediately following the shift_reg tag tells the statement how many bytes are in the array that is being acted upon by the shift operation. The final 1 in the statement is the actual data that is being shifted into the array. By shifting in a 1, we have seeded the pseudo-random number generator. If we did not seed the LFSR with something other than 0, the output of the pseudo-random number generator would be all 0s.

This code snippet uses the first tap entry from Table 1. The eight stages in the table mean that the LFSR is eight bits wide. The LFSR stages are numbered 1 through 8. In the code, we will have to use 0 through 7 instead. So, [8, 7, 6, 1] translates to [7, 6, 5, 0]. The four taps refer to the pair of XOR gate inputs that we're about to implement in the code.

The XOR gates and taps in Figure 2 match up with our translated tap numbers behind the accum0 and accum1 XOR statements. The tapx bits are representations of the current state of the associated bits in the shift_reg array byte, whose data is mirrored in the shift_reg_data byte. You can logically

Hex Dump 1. I've arranged the captured pseudo-random data in lines of 16 bytes to make it easy for you to see that the sequence repeats beginning at byte 256 (bottom line).

```
02 04 08 10 20 41 82 05 0B 17 2F 5E BD 7B F7 EE
DD BB 77 EF DE BC 78 F0 E1 C2 84 09 13 27 4E 9D
3A 75 EB D6 AC 58 B1 63 C7 8F 1E 3C 79 F3 E6 CD
9B 36 6D DB B7 6F 9F BF 7F FF FE FD FA F5 EA D5
AB 57 AE 5C B9 73 E7 CE 9C 39 72 E4 C9 93 26 4D
9A 35 6A D4 A8 50 A1 43 86 0D 1B 37 6E DC B8 70
E0 C1 83 06 0C 18 30 61 C3 87 0E 1C 38 71 E3 C6
8C 19 33 66 CC 98 31 62 C4 88 11 23 46 8D 1A 34
69 D3 A7 4F 9E 3D 7A F4 E9 D2 A4 48 91 22 45 8A
15 2B 56 AD 5B B6 6C D8 B0 60 C0 80 01 03 07 0F
1F 3F 7E FC F9 F2 E5 CA 94 29 52 A5 4B 96 2D 5A
B5 6B D7 AF 5F BE 7C F8 F1 E2 C5 8B 16 2C 59 B2
64 C8 90 21 42 85 0A 14 28 51 A2 44 89 12 24 49
92 25 4A 95 2A 55 AA 54 A9 53 A6 4C 99 32 65 CB
97 2E 5D BA 74 E8 D1 A3 47 8E 1D 3B 76 EC D9 B3
67 CF 9F 3E 7D FB F6 ED DA B4 68 D0 A0 40 81 02
04 08 10 20 41 82 05 0B 17 2F 5E .......
```



Schematic 1

think of each accumx as an XOR gate in Figure 2. Once all of the modulo-2 data is collected into the accum7 bit, the bit of modulo-2 data is pushed into the actual shift register (shift_reg[0]). The shift register mirror byte is updated and the contents of the shift register — our pseudo-random number — are printed out using the PIC's serial port. Everything inside the while(1) braces executes as an endless loop. Earlier, we said that, if everything was done correctly, our eight-bit LFSR would generate 255 pseudo-random numbers. Feast your eyes on Hex Dump 1.

Now, let's break our nice little LFSR by moving the tap on the 0 bit to the 1 bit. To do that, we simply change one C statement.

```
accum1 = tap5 ^ tap0;
becomes accum1 = tap5
^ tap1;
```

Here, we see yet another reason to implement stuff like this in software. If you had to make this change in a hardware implementation, I'd be running numbers while you were still soldering. Note that, in Hex Dump 2, our pseudo-random number sequence is changed and that it is not of maximal length (255 bytes). Depending on your application, that can be good or bad.

Suppose you have a need for more than 255 pseudo-random numbers? No problem. Check out Listing 2. To increase the width of our LFSR to 16 bits, I added another byte to the shift register array (shift_reg[2]). I also renamed the shift_reg_data byte and added a companion shift register mirror byte — shift_reg_data_high — which gives us 16 possible tap points. Since we now have two bytes in our shift register array, note the 2 in the shift_left(shift_reg,2,1) statement.

Making this change allows us to now shift across 16 bits instead of eight. The tap points for a 16-stage (bit) LFSR were taken from Table 2.

Now m = 16 and $2^{16} - 1$ gives us 65,534 pseudo-random numbers. I'll let you print them and count them.

I actually did count the 65,534 sequences just to make sure I didn't lie to you. I used the NoteTab Pro text editor and captured pseudo-random data from Tera Term Pro. NoteTab Pro has line numbers and I added a carriage return and line feed behind each number that I sent from the PIC's serial port. Once I captured all of the data, I dumped it into NoteTab Pro and erased everything beyond line 65,535. The data at line 65,535 was identical to the data in line 1. I then searched for the data in lines 1 through 65,535 and got only two matches, line 1 and line 65,535.

Shifting Out

How random is random? Well, that's all in how you see randomness. Try reversing the taps and shifting in from the right instead of the left. You'll get a whole new set of numbers that are mirror images of the left-shifted bytes. You can also pick out certain bits or invert the pseudo-random values to make alternate sets of numbers.

The LFSR code is posted on the *Nuts & Volts* website (**www.nutsvolts.com**); you can get the complete set of LFSR tables I used in this text from the New Wave Instruments site (**www.newwaveinstruments.com/index.htm**). **NV**

Table 2. Now that you have some LFSR code, you can easily try all 26 of these tap sets.

16 stages, four taps: (26 sets)
[16, 15, 13, 4]
[16, 15, 12, 10]
[16, 15, 12, 1]
[16, 15, 10, 4]
[16, 15, 9, 6]
[16, 15, 9, 4]
[16, 15, 7, 2]
[16, 15, 4, 2]
[16, 14, 13, 11]
[16, 14, 13, 5]
[16, 14, 12, 7]
[16, 14, 11, 7]
[16, 14, 9, 7]
[16, 14, 9, 4]
[16, 14, 8, 3]
[16, 13, 12, 11]
[16, 13, 12, 7]
[16, 13, 11, 6]
[16, 13, 9, 6]
[16, 13, 6, 4]
[16, 12, 9, 7]
[16, 12, 9, 6]
[16, 11, 10, 5]
[16, 11, 9, 8]
[16, 11, 9, 7]
[16, 10, 9, 6]

Hex Dump 2. This is a "broken" LFSR — or is it really "broken?" No one said that you absolutely had to use a tap table to generate pseudo-random numbers.

```
02 05 0A 15 2A 54 A9 52 A4 48 91 23 46 8C 19 32
64 C8 90 21 43 86 0C 18 30 61 C2 85 0B 17 2F 5E
BC 78 F0 E1 C3 87 0E 1D 3A 74 E8 D1 A2 45 8B 16
2D 5B B6 6D DA B5 6A D5 AA 55 AB 57 AE 5D BB 77
EF DE BD 7A F5 EB D6 AD 5A B4 68 D0 A0 40 81 03
07 0F 1F 3F 7E FD FB F6 EC D9 B2 65 CA 95 2B 56
AC 58 B1 62 C5 8A 14 28 51 A3 47 8E 1C 38 71 E2
C4 88 11 22 44 89 13 27 4E 9C 39 73 E7 CE 9D 3B
76 ED DB B7 6F DF BF 7F FF FE FC F9 F3 E6 CC 98
31 63 C7 8F 1E 3D 7B F7 EE DC B8 70 E0 C1 82 04
08 10 20 41 83 06 0D 1A 35 6B D7 AF 5F BE 7D FA
F4 E9 D3 A7 4F 9E 3C 79 F2 E4 C9 92 24 49 93 26
4C 99 33 66 CD 9A 34 69 D2 A5 4A 94 29 53 A6 4D
9B 36 6C D8 B0 60 C0 80 01 02 05 0A 15 ....
```

Listing 2. Here's some code to fire up a 16-bit LFSR.

```
#include <16f877.h>
#include <f877.h>
#device ICD=TRUE
#device *=16

#fuses DEBUG,HS,NOWDT,NOPROTECT,NOBROWNOUT,NOLVP,NOWRT
#use delay(clock=20000000)
#use rs232(baud=57600,xmit=PIN_C6, rcv=PIN_C7)
#id 0x0401

int8 shift_reg_data_low,shift_reg_data_high,result,shift_reg[2];

#bit tap15 = shift_reg_data_high.7
#bit tap14 = shift_reg_data_high.6
#bit tap13 = shift_reg_data_high.5
#bit tap12 = shift_reg_data_high.4
#bit tap11 = shift_reg_data_high.3
#bit tap10 = shift_reg_data_high.2
#bit tap9 = shift_reg_data_high.1
#bit tap8 = shift_reg_data_high.0

#bit tap7 = shift_reg_data_low.7
#bit tap6 = shift_reg_data_low.6
#bit tap5 = shift_reg_data_low.5
#bit tap4 = shift_reg_data_low.4
#bit tap3 = shift_reg_data_low.3
#bit tap2 = shift_reg_data_low.2
#bit tap1 = shift_reg_data_low.1
#bit tap0 = shift_reg_data_low.0

#bit accum7 = result.7
#bit accum6 = result.6
#bit accum5 = result.5
#bit accum4 = result.4
#bit accum3 = result.3
#bit accum2 = result.2
#bit accum1 = result.1
#bit accum0 = result.0

void main(){

        shift_reg[0] = 0x00;
        shift_reg[1] = 0x00;
        shift_reg_data_low = 0x00;
        shift_reg_data_high = 0x00;
        result = 0;
        shift_left(shift_reg,2,1);
        while(1){
                accum0 = tap15 ^ tap14;
                accum1 = tap12 ^ tap3;
                accum7 = accum0 ^ accum1;

                shift_left(shift_reg,2,accum7);
                shift_reg_data_low = shift_reg[0];
                shift_reg_data_high = shift_reg[1];
                printf("%X%X\r\n",shift_reg[1],shift_reg[0]);
        }
}
```

Tech Forum

QUESTIONS

I need an IR circuit to connect to the COM port of my PC, which is running Windows XP. I am using a Timex Ironman 10 alarm watch, which can be programmed via an IR port. Normally, it will work using Windows 98/ME (but not XP) using the monitor screen to send data to the watch. Can anyone help with a simple circuit for a transmit IR system that uses a com port?

#8041 **Ray Metzger**
via internet

I need a circuit to transmit and receive a laser signal to detect small, non-moving objects over 100-150 yards away from a portable power supply. The circuit should be able to determine the range to the object and display it during daylight periods. Also, the circuit should be able to discriminate the object from its surroundings, either by applying special reflective coatings to the objects or by making the objects relatively bright as compared to surrounding objects.

Is there any circuitry in the public domain that uses available microcontrollers or discrete components?

#8042 **C. E. Morris**
via Internet

I live in a rural area, in a fairly well shielded building. Cell phone signals are sporadic inside, except when I am very near windows. Are there any proven passive antenna relay systems that work (antenna outside coupled to something in the attic) or something relatively simple that I can construct? I'm not positive, but I believe that service here is still only on the 800 MHz band.

#8043 **Joe Pitman**
via Internet

Does anyone know of a simple circuit where an LED would indicate if a phone line was busy or not without putting the line off-hook while doing this during an incoming ringing cycle?

#8044 **Anthony Thomas**
Columbia Falls, MT

I built an interesting science project for the school earlier this spring called a "NASA Power Factor Motor Controller." It was designed to save about 60% on our electricity bill and was based on a project published in the October 1979 issue of *Popular Electronics*, in an article by Myles H. Marks. I followed every detail of the construction article and — even after troubleshooting it for weeks — it fails to work. Review of the design by an engineering professor from a nearby university revealed that the design doesn't practically function, even though NASA owns the patent (4,052,648)! He felt that this project was just another "perpetual motion" boondoggle. If anyone has had similar experiences with this project and was able to make it work, could you please explain how you did it?

#8045 **Harry Gibbens, Jr.**
Payson, UT

I cannot seem to find any good information on IR filters for video cameras; for example, I don't know if they come in different densities, strengths, or colors. Can someone write a brief explanation for me?

#8046 **Bob Oleksiak**
Melbourne, FL

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

Send all material to *Nuts & Volts Magazine*, 430 Princeland Court, Corona, CA 92879, OR fax to (951) 371-3052, OR email to forum@nutsvolts.com

ANSWER INFO
• Include the question number that appears directly below the question you are responding to.
• Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
• Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
• Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO
To be considered
All questions should relate to one or more of the following:
1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions
• No questions will be accepted that offer equipment for sale or equipment wanted to buy.
• Selected questions will be printed one time on a space available basis.
• Questions may be subject to editing.

Helpful Hints
• Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
• Write legibly (or type). If we can't read it, we'll throw it away.
• Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

ANSWERS

[4042 — April 2004]
I am looking for a supplier of vacuum tube radio kits for my daughter and me to build. Does anyone know of a reputable

kit dealer?

#1 PV Scientific Instruments sells both single and twin triode regenerative receiver kits. The single triode kit includes a set of plug-in tuning coils. The twin triode radio covers 550-1750 KHz longwave and 29-46 MHz shortwave. Their web page is at **www.arcsandsparks.com** Their address is 42 King St., Trumansburg, NY 14886, (607) 387-6752. They also sell crystal set kits. A lot of very good information on crystal sets is provided by The Xtal Set Society at **www.midnight science.com**

Tom Tillander
Bay Village, OH

#2 My favorite supplier is the Borden Radio Company at **www.xtalman.com** They have several simple inexpensive radio kits, including a one tube Armstrong kit. The power is supplied by batteries for safety and simplicity — no power transformer is needed. Allow one evening for building the kit and — if desired — another one for finishing the wood base and allowing the finish to dry. The instructions are simple and well illustrated. I especially appreciate the history and theory that accompanies the kits.

Steve Uhrig
Street, MD

[5048 — May 2004]

*Is there equipment for discovering the identity of a phone caller that the *69 dial back service reports as an unreachable private line?*

The right to privacy is the reason the phone equipment is designed to react the way you described. The audio paths (your line to another line) are controlled by a computer, but the computer is not accessible from the line. It keeps people from doing things like you want to do.

Dennis Hewett
Frontenac, KS

[50411 — May 2004]

Can anyone suggest a source for negative-acting, photo-sensitized boards, such as those Kepro used to supply?

#1 You may make your own negative-acting photosensitized boards using Kodak Photo Resist (KPR), which is available from P C & E; you can call them at (610) 296-8585. It is packaged in quart bottles.

To make a photosensitized board, first clean it thoroughly using a fine emory cloth. Wipe all the dust off with a clean tissue. Then, under dark light conditions, apply a small quantity of the resist to the board and spread it evenly with a cotton swab. Place the board in a vertical position in a light-proof box to let it drain. Bake it in a *pre-heated* 100° F oven for about 30 minutes. The board is now ready for exposure.

Caution: It is imperative that no

moisture from the box or gas oven be present during the baking procedure. Otherwise, the resist will become porous.

Anthony J. Caristi
Waldwick, NJ

#2 D & L Products, Inc. (DALPRO), based in St. Louis, MO is now supplying the products formerly offered by Kepro Circuit Systems. They have kept the old catalog numbers that Kepro used. You can reach them at (314) 575-7717 or on the web at **www.dalpro.net/**

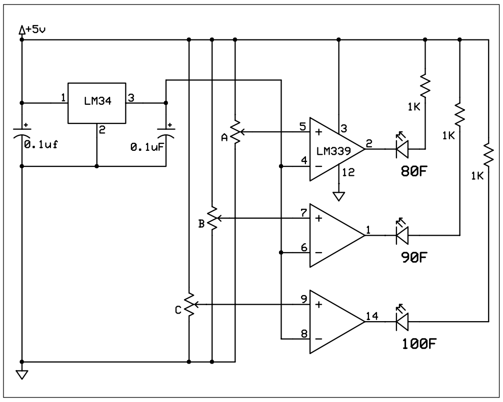
Barry Scanlan
Owensboro, KY

[110312 — November 2003]

I'm looking for a temperature sensing circuit that will light each of three LEDs at approximately 80° F, 90° F, and 100° F.

A few years ago, *Poptronics* had an article that featured a chip called an LM34 temperature sensor. It was a three terminal device that operated on 5 volts. The chip has a range of 0-300° F and outputs exactly 10 mV per degree F. If this output is supplied to an LM339 quad comparator, the circuit can be made to indicate just about any temperature from 0-300° F. In the example below, pots A, B, and C are 100K and should be set to 800 mV, 900 mV, and 1.00 V, respectively, so the LEDs light at 80° F, 90° F, and 100° F.

Craig Shippee
South Walpole, MA



[12034 — December 2003]

I am considering building a CNC milling machine for PCB prototyping. I need software to drive the X, Y, and Z axes. Where can I find a shareware or low cost Windows program that will accept HPGL or Gerber files as input and output motion control code?

Years ago, there were shareware programs that used Gerber files to control three axis CNC machines — Dancad3d 2.5, Dancam 2.52, and Danplot 2.52. I went to **www.dancad3d.com/** but couldn't find the old ones. They will let you download new ones for "Beta testing" purposes, but there are a lot of disclaimers and EULAs. However, I found another site with downloads at **www.luberth.com/cstep/software.htm** has links to many other programs.

Dave Hogan
Montauk, NY

Protek 'Next Generation' Digital Multimeter

Well equipped DMM with True RMS, 3-3/4 Digits, RS-232C Interface, 4000 Count, Auto-Ranging, Analog Bargraph 10MHz Freq. Counter & much more !

Item# PROTEK506 ~~$149~~ **Sale $99.00 !**

Details at Web Site
> Test Equipment > Digital Multimeters/World Beater Prices

ESD Safe Thru-Hole Soldering/Desoldering Repairing System

Item# CSI701

Only $199.00!

High precision thermostatically controlled station w/ 35W Iron & desolder gun. Built-in double cylinder vacuum pump.

Details at Web Site
> Soldering Equipment & Supplies
> Rework Stations

Digital Laser Tachometer

*5 digit, 6" LCD Display
*2.5-99,999 RPM test range
*Auto-Ranging
*2" to 80" test range
*memory function

$49.00!

Item# DT-6234C

Details at Web Site
> Test Equipment > Specialty Test Equipment

Protek 605 60V/5A Power Supply

Item# PROTEK605 $119.95

Unbelievable Price!

At this **rock bottom price** you get a beefy 60V and 5A of continuously variable power. It is short circuit and overload protected and provides excellent regulation and ripple specs. Separate easy to read analog meters allow for monitoring of voltage and current.

Details at Web Site *Limited To Stock On Hand*
> Test Equipment > Power Supplies

Triple Output Bench Power Supply

with Large LCD Displays

Output: 0-30VDC x 2 @ 3 AMPS & 1ea. fixed output @ 5VDC@3A
Source Effect: $5x10^{-4}$=2mV
Load Effect: $5x10^{-4}$=2mV
Ripple Coefficient:: <250uV
Stepped Current: 30mA +/- 1mA
Input Voltage: 110VAC

CSI3003X3..$179.00 (qty 5+..$169.00)

Details at Web Site
> Test Equipment > Power Supplies

www.CircuitSpecialists.com

*Easy to Navigate
*Includes a Search Engine That Really Works
*New Items Added Constantly

Item# CSI825A++

FANTASTIC VALUE!!

MicroProcessor Controlled !

Includes 4 Nozzles !

Only $199.00!

SMD RE-WORK SYSTEM w/Vacuum Pick-up tool.

Details at Web Site
> Soldering Equipment & Supplies > Rework Stations

Circuit Specialists Soldering Station w/Ceramic Element & Seperate Solder Stand

new!

Best Buy $34.95!

*Ceramic heating element for more accurate temp control
*Temp control knob in F(392° to 896°) & C(200° to 489°)
*3-prong grounded power cord/static safe tip
*Seperate heavy duty iron stand
*Replaceable iron/easy disconnect
*Extra tips etc. shown at web site

Item# CSI-STATION1

Rapid Heat Up!

Also Available w/Digital Display & MicroProcessor Controller

Item# CSI-STATION2

$49.95

Details at Web Site

SMD Hot Tweezer

Adaptor Fits CSI Stations 1 & 2, and also CSI906

Item# CSITWZ-STATION **$29.00**

> Soldering Equipment & Supplies > Soldering Stations

Circuit Specialists Inc.

In Business Since 1971

SMD RE-WORK SYSTEM w/Solder Iron

Item# CSI906

Incredible Deal! only $169.00!

Includes 4 Nozzles !

Details at Web Site
> Soldering Equipment & Supplies > Rework Stations

Hand-Held 3.0GHz Universal Counter

*10 digit LCD Display
*High speed 300MHz direct counter w/0.1Hz resolution
*50 Ohm input for full range 1MHz to 3.0GHz coverage
*Ultra sensitive synchronous detector w/16 segment bargraph display of RF signal strength
*4 selectable gate speeds
*Hold switch locks display
*Low power consumption

With Field Strength Measurement

INCLUDES:
*removable telescoping antenna
*Internal 4AA Nicad battery pack
*9VDC, 500mA wall charger
*Pocket Sized Tester

Now Only $99.00!

Item# FC1002

Details at Web Site > Test Equipment > Frequency Counters

1500W Heat Shrink Gun

Item# ZD509

With a temperature range of 392°F to 932°F & two power settings, 800W and 1500W, it will shrink tubing effortlessly. A thermo-control rotating knob on the rear of the unit will adjust the temperature electronically for precise control, while the three-way trigger switch adjusts the speeds. Comes complete with a concentrator air nozzle and a retractable stand.

Details at Web Site **Only $18.95**
> Heat Shrink Tubing SoftTube Our Own Brand

Protek 100MHz Realtime Scope

Super Blowout Price!

2 Ch Dual Trace
6" Internal Grid
ALTMAG
ALTTRIG
TV Sync
5 Vertical Modes

Brand New Not Refurbished! Includes 2 scope probes

A $975.00 Value !

Item# 6510

100MHz only *$499.00*

While Supplies Last!

Details at Web Site > Test Equipment > Oscilloscopes/Outstanding Prices

Single Output DC Bench Power Supplies

As Low As $85.00!

High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

*Source Effect: $5x10^{-4}$=2mV
*Load Effect: $5x10^{-4}$=2mV
*Ripple Coefficient:: <250uV
*Stepped Current: 30mA +/- 1mA

CSI3003X: 0-30v/0-3amp/1-4..$89.00/5+..$85.00
CSI5003X: 0-50v/0-3amp/1-4..$99.00/5+..$95.00
CSI12001X: 0-120v/0-1amp/1-4..$109.00/5+..$103.00

Details at Web Site > Test Equipment > Power Supplies

Hot Air Gun w/Digital Display for SMD's

new!

Now, precise temperature and airflow control is at your finger tips with this digitally controlled Hot Air Gun. Quickly solder and de-solder DIP, BGA and SMT electronic components. Plus, be able to shrink, "Heat shrink tubing".

CSIHOTGUN-2 $89.00

Details at Web Site
> Soldering Equipment & Supplies > Soldering Irons

[redacted]ximize your
[redacted] Summer Special!

Sensors and displays are a perfect way to add more excitement to your Parallax Summer Special Kit or to any BASIC Stamp project. Featured accessories (clockwise from top):

- **2 x 16 Seetron Serial LCD (#27910; $49)** The right choice if you require a small footprint and low current draw. Commands allow scrolling, cursor positioning, and more.
- **Memsic 2125 Dual-Axis Accelerometer (#28017; $29 $25)** A thermal accelerometer capable of measuring dynamic and static acceleration.
- **FlexiForce Sensor Demo Kit (#30056; $25 $21)** This touch sensor has an ideal output for A/D conversion. The active sensing area is a 0.375" diameter circle at the end of the sensor.
- **Sensirion Temperature/Humidity Sensor (#28018; $29 $25)** A smart sensor for humidity and temperature in a small package that incorporates the analog to digital interface.

Order online at www.parallax.com or call the Parallax Sales Department toll-free at 888-512-1024 (M-F, 7am - 5pm, PST).

Hurry! Only 1 month left to get the Parallax Summer Special.

The Parallax Summer Special kit includes a HomeWork Board™ project platform with a BASIC Stamp®2 microcontroller built onto the board, the **What's a Microcontroller?** (WAM?) Text, CD-ROM with software, and a component kit that includes a Parallax Standard Servo, LED's, resistors, capacitors, sensors, a speaker and more. Order the **Parallax Summer Special** (#90005; $79.00) until 09/01/04, or while supplies last.

PARALLAX

Circle #154 on the Reader Service Card.